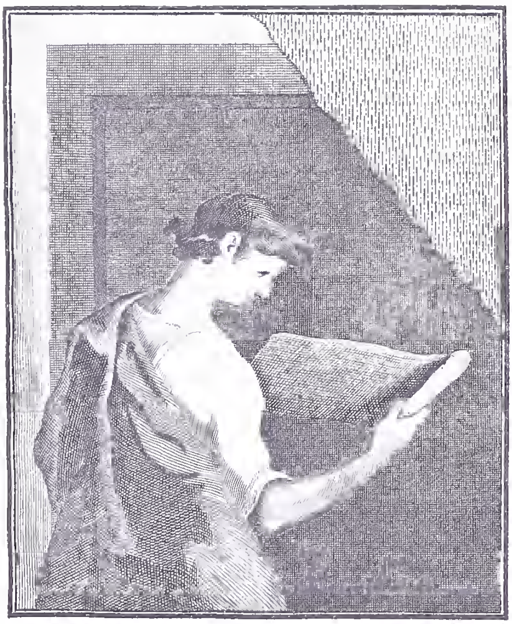
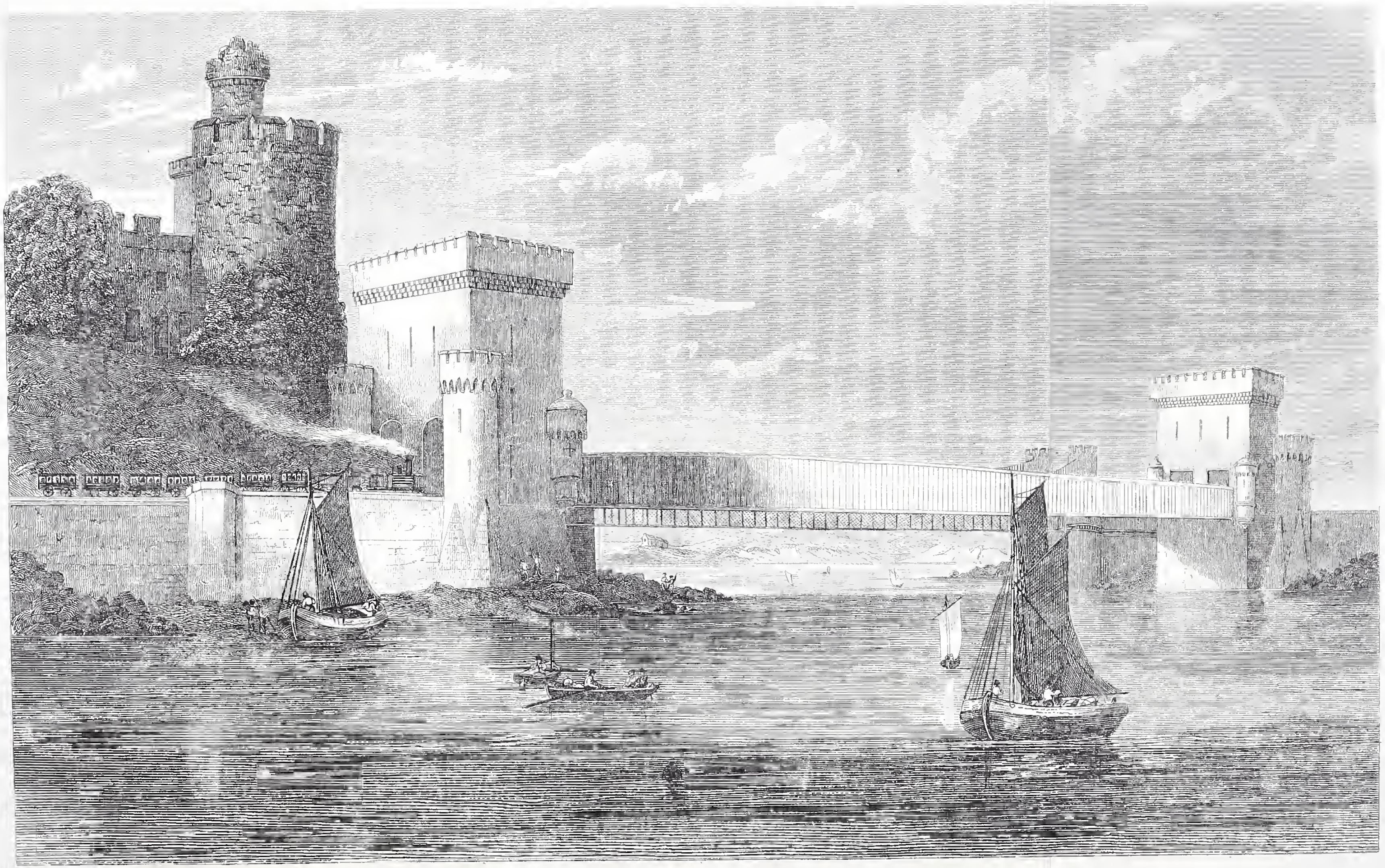




THE CONWAY TUBULAR BRIDGE.


THE

# IMPERIAL JOURNAL

OF

## ART, SCIENCE, MECHANICS AND ENGINEERING,

EMBRACING TREATISES ON

ANATOMY AND PHYSIOLOGY,
ARCHITECTURE, ASTRONOMY,
AGRICULTURE,
BOTANY, CHEMISTRY,
DAGUERREOTYPING,
ELECTROTYPING,
GEOGRAPHY, GEOLOGY,
HISTORY, HORTICULTURE,
MATHEMATICS:—ALGEBRA, GEOMETRY, TRIGONOMETRY,
MECHANICAL DRAWING AND PERSPECTIVE,
MECHANICS, MEDICINE,
NATURAL PHILOSOPHY,
NAVIGATION, PHRENOLOGY,
POLITICAL ECONOMY.

ALSO, THE

ARTS OF DYEING AND BLEACHING—IRON AND BRASS FOUNDING,
THE MANUFACTURE OF SODA—GERMAN SHEET GLASS,
&c. &c. &c.

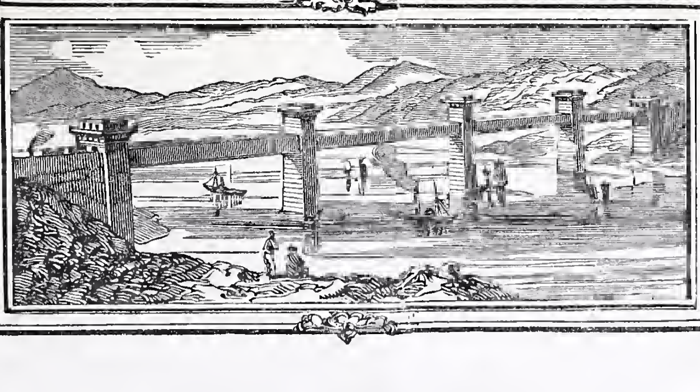
AND

A SERIES OF PRACTICAL PAPERS ON THE STEAM-ENGINE,

ILLUSTRATED BY BEAUTIFUL DRAWINGS OF LAND, MARINE, AND LOCOMOTIVE ENGINES.

VOL. 1

MANCHESTER: JAMES AINSWORTH,
87 AND 93 PICCADILLY.



# PREFACE.

THE object of the present undertaking is to PROMOTE THE EDUCATION OF THE WORKING CLASSES—to afford them an easy means of acquiring every kind of useful knowledge. There are already in existence many periodicals, designed to amuse, instruct, improve, and advance the interests of the people generally, or of particular classes. Without disparaging these—many of which are excellent, so far as they extend—we do not find any one upon the comprehensive plan, or in the peculiar style, adapted to the wants of the people. Some important department is omitted by each. Few follow a systematic course, and the working man cannot afford the means or the time for the perusal of more than one or two.

There appears a want of *some one useful work*, affording—at a cheap rate, and in such portions as may be easily perused by those whose time is chiefly occupied in providing for the wants of the day—the means of acquiring all that knowledge which will assist them to perform well the various duties of life; which will improve, as men, workmen, and citizens, those who should have been taught by a National System, in schools and colleges for the working classes, from treatises used there as text-books. But this is not done, nor is it likely that it will be effected soon. We therefore propose, by our present publication, *to place the materials for self-instruction, in every department of truly useful knowledge, within the reach of all classes.* The periodical form is popular, and subscribers to the work will, in the course of time, be possessed of a complete system of instruction in every useful department of human knowledge. It will provide him with agreeable and interesting reading for himself and his family, and it will, at the same time, furnish him with every information regarding the principles of his art.

Although suited to all classes of readers, this work is principally intended to strengthen the intellect, elevate the moral character, and improve the social condition of the operative classes, by instructing them in the principles and practice of their several vocations. Notwithstanding the boasted facilities possessed by the working classes of acquiring education, the present work will be found a useful auxiliary. The general way in which the working classes attain scientific knowledge is, by attending Mechanics' Institutions. The benefits of such institutions cannot be too highly extolled; but the experience of every student must teach him, that something more than the fleeting words of the lecturer is necessary to make his studies satisfactory. Reading and investigation are necessary; and although our libraries afford an easy access to books, those books cannot be retained long enough to afford time to digest their contents. The next resource is to purchase books; but the high price of scientific works places them beyond the reach of working men. There is, therefore, a great desideratum, which it is the purpose of the Imperial Journal to supply. Each illustrated essay on Science will be a lecture—the whole work a Mechanics' Institute.

One of the many advantages to be derived from the study of general science, independent of its practical applications, is the amount of wholesome discipline which the mind undergoes in its investigations, and the influence which it exerts in the formation of the moral and intellectual character. By dint of application, the mind attains strength, the judgment is matured, and the individual acquires correct ideas of his own powers, and the best modes of applying them. Taught by habitual analysis of evidence rightly to esteem *facts*, and trained by a practical logic to the vigorous use of his reasoning faculties, he insensibly contracts an abstract love of truth, and renders the mental powers pliant and ready to bend to objects at once useful and sublime. He stands, in some degree, protected against the insidious arts of sophistry, and the bewilderments of superstition; and no reasoning, however specious, will make him receive as true what appears incongruous, or cannot be recommended by analogy, or submitted to the test of demonstration. He may be deficient in many ornamental accomplishments, which it were desirable to possess; but there are none of the

honourable avocations of life in which such discipline of the mind will not be abundantly useful.

Refraining, in the present instance, from any lengthened disquisition on the pleasures and advantages of knowledge, we prefer giving a general idea of how it is intended the work should be conducted.

**Natural Philosophy.**—The various physical sciences generally comprehended under this term, will form the subject of separate, and, as far as possible, distinct treatises. Following the grand object in view—Popular tuition—it is almost needless to say, that the subjects will be treated in a manner the most popular and explicit. The following order of arrangement will, as nearly as possible, be adhered to, in as far as the elementary treatises are concerned:—

Definition and distinction of the various branches of Science.—Matter and its properties.—Mechanics, embracing Statics and Dynamics, or the laws which regulate solid bodies at rest and in motion.—Hydrostatics, or the laws which regulate fluids in a state of rest.—Hydraulics, or the laws which regulate the motion of liquids.—Pneumatics, or the laws which regulate the motion of aeriform bodies.—The science of heat will then follow, leading to a consideration of the origin and progressive improvement of the steam-engine, steam navigation, locomotives, steam-carriages on common roads, &c.—Electricity, including Galvanism, Magnetism, Electro-Magnetism, and the Electrotype.—Optics and optical instruments.—Astronomy, &c. In this department will be familiarly explained the various apparatus and machines used either for the purpose of experiment, or practically applied in the useful arts of life.

**Chemistry,** so important in its applications to our arts and manufactures, and so interesting in its explanations of the phenomena of the physical world we live in, will claim a large share of our attention. The *necessity* which presses the cultivation of this branch of human knowledge among us, as a community of manufacturers, independently of the more elevated claims of civilized man to all the advantages which his position places within his reach, is too manifest to escape the most obtuse observer. There is hardly a useful art, and there is no extensive branch of manufacture, which is not dependent upon Chemistry for its successful practice; and to those who have no immediate interest in any art or manufacture, it stands forth as the interpreter of all the material phenomena within and around us, and as a means of mental discipline of a high order.

Our Chemical course will differ from the systematic treatises already extant, chiefly in its following a more natural method; that is, a more gradual path from the known to the unknown, and in its greater attention to the practical applications of the science. We do not profess to furnish under this head a minute detail of every chemical art and manufacture. Such a plan would lead us into interminable repetitions. But viewing our science as the Pharos which the hands of man have erected in the sanctuary of the operations of art and nature, in order to throw a light over all its details, we shall pursue steadily the general principles of the science, and class under each the operative processes which emanate from it. Following this method, we shall find all the numerous operations of industry united in close relationship, and regulated by principles in some measure common to them all. The discussion of the general laws of chemical action, and the description of the principal bodies on which chemical action is exercised, point directly to a comparative analysis of numerous industrial processes, and explain innumerable effects, observable in the practical application of the science.

In selecting illustrations from the Arts, we shall uniformly give a preference to those which involve the greatest amount of practical importance. Our discussions will blend, as far as possible, the strictly scientific with the elementary and popular character; and the numerous experiments which it will be necessary to describe—for the science is one entirely of experiment—will be minutely detailed, and illustrated, when necessary, with drawings of the apparatus employed. This will enable every intelligent *student*—for he who would know chemistry must be something more than a mere *reader*—to verify every result announced, and to satisfy himself o the accuracy of the investigations described. Practice is necessary to the successful prosecution of the science. Without this, all teaching is abstract; there is nothing upon which the mind may be detained; and the mere principle, verbally transmitted, is soon obliterated from the memory, or takes a wrong direction there. The experimenter, on the contrary, reflects in his own experience all the light that is transmitted to him; he sees in his operations the confirmation of all that is told him; he compares the theory with what he does, and finds an identity which strikes a deep impression of permanent value.

"It may be thought by some, that chemical experimenting must be attended with vast difficulties and expense, and it is true that a complete course of chemical experiments can only be had where the proper facilities for operating are to be met with. But let any one provide himself with a few slips of glass, a few phials, with acids and alkalies, and a small quantity of fifty or sixty of the more important chemical preparations—all of which, both apparatus and materials, he can procure for five or six shillings at the utmost—and he not only provides himself with a small museum, to which he can continually refer, but can also perform again and again, with a part of the materials, several thousand demonstrative experiments of the greatest practical importance."

**Anatomy** and **Physiology** will be treated under the following arrangement:—

1. The skin and perspiration.
2. The fasciæ, or fat, and its uses.
3. The muscles and muscular action.
4. The bones, their mechanism and uses.
5. The bowels and digestion.
6. The kidneys and urinary secretions.
7. The lungs and respiration.
8. The blood vessels and sanguineous circulation.
9. The brain, nerves, and animal life.
10. Animal absorption, conservatism, and production.
11. Animal decay, death, and decomposition.

In addition to Anatomy and Physiology, there will be given occasional essays on the laws of the animal economy in a morbid state, exhibiting the phenomena of disease, with the means of prevention and cure. Comparative Anatomy will also be treated, and Animal Chemistry. The reader will thus not only learn to understand his bodily structure and functions, but likewise his relation to the lower animals, and know the names and combination of the elements of which he is composed. The essays will be illustrated by plates, exhibiting the beautiful mechanism and laws of the human body; and sufficient care will be taken to explain unusual terms when their use is unavoidable.

**Geology** and **Natural History.** — Concise and distinct views will be given of the leading phenomena of animate and inanimate nature, in the ancient and modern conditions of our globe. Geology may be considered as a history of these conditions, from the time when the earth assumed a consolidated form, to the present day. And as, without understanding the construction of existing animals, a true knowledge of the organic changes which have occurred on the surface cannot be obtained, it shall be our object to describe such peculiarities of the existing animated tribes, as tend to throw light, not only on the present economy of nature, but upon the changes which have been effected in the construction and dispersion of animal life, since the time it began to exist. While we attend to these features, certainly by far the most extraordinary in the history of our planet, we will endeavour to give a luminous view of the order of its stratification—the agencies by which it has been produced—and the alterations it has undergone—together with a history of the volcanic and other mineral productions, peculiar to the various formations, which constitute its crust. A series of articles from the same pen will also appear, illustrative of the mineral resources of the country, and of the phenomena peculiar to our Coal Fields.

In the execution of this part of our work, care will be taken to accommodate the language to the comprehension of the general reader, by the insertion of explanations of such terms as may not be generally understood.

**Mathematics.**—The Mathematical department will be both comprehensive and perspicuous, and, above all, sufficiently familiar to enable every reader of common capacity and industry, to acquire an accurate knowledge of the principles, and most of the fundamental propositions of the science, with their ready application to the practical purposes of the architect, engineer, and general mechanic. Aware of the very imperfect elementary instruction, even in the ordinary branches of vulgar arithmetic, which usually falls to the share of the industrial classes, before they are hurried into the laborious and all-engrossing duties of their trade, we shall not hesitate to risk the disapprobation of the more learned and fortunate of our readers, by descending, in accordance with our general plan, to the first elements; and there laying a secure foundation, gradually raise a superstructure just in proportions, and exhibiting in marked features the practicalness of its objects.

The elements of Mathematics usually taught comprise Arithmetic, Algebra, Geometry, and Trigonometry; and for some special purposes, it is convenient to recognise these divisions as distinct sciences. Their connection is, however, intimate, and cannot be dissolved without manifest violence to the whole. The only line of distinction which can be traced with any degree of certainty, is between Algebra and Geometry. These branches respectively include Arithmetic and Trigonometry, and occupy fields blending indeed into each other, but presenting features peculiar and distinctive.

Bearing, therefore, strictly in mind the logical dependence of the recognised divisions of our subject, and that our ultimate object is the development of a complete system of Mathematical Science, we shall endeavour to lay a solid foundation for subsequent progress, in a clear and compendious exposition of the principles of Arithmetic and Algebra. A competent acquaintance with these is necessary to insure that facility of computation which every practical man ought to attain, and that ready comprehension of scientific theorems and formulæ which forms the key to all the stores of higher knowledge. Geometry, Trigonometry, and Conic Sections will follow; and we confidently hope, before quitting this field of our labours, to be able to proceed with a full certainty of being eagerly followed, through the very highest ramifications of the science, by many who, at this hour, are wholly unacquainted with the simplest proposition which it involves.

Throughout the course we shall furnish such examples and illustrations as may appear best suited to render the subject clearly intelligible, and its connection with other branches of knowledge strikingly manifest. We shall, moreover, in every case, endeavour, clearly and concisely, to explain the modes and forms of the operations introduced, and shall enunciate no rule without at the same time furnishing its *rationale.* Nothing shall induce us to

imitate that system of teaching, which attempts to reduce all mathematical knowledge to the mere learning of a certain amount of rules by rote. The business of all sound education is with the understanding; knowledge which is intended for the memory, and takes its stand there exclusively, is a deception upon the individual and upon society, and can claim no place in a system of rational education.

**History.**—Considering the Civil History of Mankind as a branch of study calculated to interest and benefit all classes of readers, we shall present a series of articles on this important subject. The first article will be introductory to the rest, considering how history ought to be studied—the nature of historical evidence—the advantages of studying history. The series will then go on to enumerate the sources from which historical evidence is drawn, and attempt to point out their relative value; with brief expositions of the laws of evidence, and how those laws ought to be applied to the sources of historical evidence adduced; the orgin and improvements in the various methods of computing time, principally with reference to the art of reconciling various modes of computation, and ascertaining dates. The origin and progress of geographical science will follow, to give a knowledge of the relative position of the scenes of historical events, as furnishing a means of testing the accuracy of historians, and to reconcile seeming contradictions. For a similar purpose, and as a means of tracing the advance of civilization amongst nations, a brief exposition will be given of the theory and history of languages.

Having discussed the foregoing subjects, their practical application will be shown with the history of European civilization, commencing with the earliest records of the Roman republic, and embracing, at the close, all the States of Europe, the United States of North America, and European Colonies in various parts of the world. This field, without reverting to the infancy of civil society, leads us back, as far as authentic records extend, to the origin of European opinions concerning government, morals, and religion, which are the framework of European society.

These foregoing subjects will form the principal topics to be treated in a regular series. So soon as they have advanced a certain length, there are other sciences, of a more abstruse nature, which will be commenced and treated in a similar elementary manner. Attention will be paid to enlivening the heavier studies of the sciences, by the more imaginative and amusing, though useful department of general literature—by the lessons which may be learned from the biography of the dead, and the records of those who have spent their lives in exploring foreign lands. It will be impossible to overtake, all at once, the wide range here laid down; but it will ever be our aim and constant study to fulfil every promise advanced.

THE

# IMPERIAL JOURNAL

OF

# ART, SCIENCE, MECHANICS, AND ENGINEERING.

## INTRODUCTION TO THE STUDY OF PHYSICAL SCIENCE.

It is very aptly remarked by one of our most eminent teachers of physical science, that there are two great errors commonly committed by those who enter upon a systematic course of physical inquiry, and often by those who undertake to direct such studies: the first is, the neglecting to form a proper connection with previously acquired knowledge, the undervaluing the results of ordinary experience as parts of the system, as the first rounds of that intellectual ladder, by which they aspire to scale the lofty heights of philosophy: the second is, the substitution of names for things, the vague acquirement of certain terms, certain forms of expression, instead of a real understanding of objects and principles to which they have been applied. The process may be repulsive to the self-sufficiency of imperfect knowledge, but when invited to reflect and reason upon the simple observations of childhood—simple indeed, but not more easy than those he will be called upon progressively to make—the student ought to feel no more offence than when he is referred in his mathematical studies to the self-evident truth, that "a whole is equal to the sum of its parts." It is from the known that he must ascend to the unknown, and it is all-important that he make his footing sure, and miss no step by the way.* It is the natural tendency of the mind to rush at once upon its object, and it may require an effort to cure it of this precipitancy; but when once convinced that those homely facts which it has gathered in the routine of every-day experience, are the real foundation of physical knowledge—that in them lie treasured the estimable principles which will carry it surely to the goal on which it gazes so intently, it will eel less reluctance to examine the path, and to cull, as it passes along, the pleasures which are strewed on the right and on the left; it will, in fact, unbend its high and lofty attentions, and acknowledge that the principles of physical science are but the principles of common sense.

But although facts—and homely and every-day facts—are the *substance* of our scientific knowledge—the real material of the superstructure, something more than mere passive observation, is needed in the erection of the edifice. The statue is not a mere block of marble; man's genius has given it the fine proportions of the living form, and we forget the material as we look upon the image. Can we admire a magnificent structure which architecture has raised, and say that it is nothing more than the rude unshapen materials of the neighbouring quarry? The rough blocks which the quarry furnished have now the impress of intelligence upon them, and are become the parts of an harmonious whole. So it is with science: its foundation and its elements are the familiar experiences of every man's life; but it is only by connecting together the results of observation, and reducing them to order—stamping upon them the impress of thought and reason—that they become science.

It must not, however, be thought, that in building the structure of science from the common materials which experience furnishes, that we proceed by any opposite method from that which we practise in the common occurrences of life. The method by which the mind pursues its practical investigations, bears, under most circumstances, a remarkable uniformity. Something strikes the attention—something which we may suppose not to be within the ordinary range of our every-day observation, and the mind immediately suggests its familiar inquiry—what can it be? The circumstances are examined, and a supposition is formed; it may be the merest conjecture, and we try whether it embraces all the conditions of the case. It may fail, but we guess again, and again try our supposition by the same test. We proceed in this tentative way, till our reason is satisfied that we have taken a right view of the subject. The method we pursue in formal science differs in no respect from this. The appearances, or *phenomena*, as we call them, are examined and compared. At first they seem but a series of facts—a series of insulated and independent links of a chain of accidents—all complexity and irregularity. But as observation enlarges, a uniformity begins to appear; and as the mind compares them, and reasons respecting them, it perceives a similarity, nay, an identity, which impresses irresistibly upon it a conviction that they are related either as cause and effect, or as the common effect

* Daniel's Philosophy.

of a single cause. The governing principle is sought for —not the ultimate *cause*, for this philosophy does not presume to investigate; but the general principle by which their varieties and modifications are to be explained; and making use of experience, personal, written, and traditional, the accumulated experience of all mankind in all ages, as the data, a general solution is attempted. It may at first be unsuccessful for want of comprehensiveness; but supposition after supposition is tried—some erroneous, and some partially correct—till at length, by dint of unwearied investigation, link after link of the chain is traced to its connection, and the *law* is finally evolved; that is, the governing principle which combines them together in one comprehensive explanation, and this we call the *theory*.

This process, by which a law is made out or inferred by the consideration of a great many facts, is what is called *induction*. It is the method inculcated by Bacon in his celebrated *Novum Organum*, and it is that by which we derive all certain and accurate knowledge of natural laws. But still it is only the first step towards the complete establishment of a theory; for it is impossible for the mind to rest satisfied with its explanations of the phenomena of nature, until it has traced out the law by an inverted process, making the theory the foundation of its reasoning, and shown by strict argument, that the facts observed must follow from it as necessary logical consequences. It is only, indeed, when a theory enables us to deduce from it, by a series of propositions necessarily connected, all the particular phenomena of that class, both observed and which may arise—that is, to *predict* what will take place at particular times and under particular circumstances—that we have entire satisfaction of its truth. The verifications of this practical kind abound in every department of physics. Thus Newton established a theory of gravitation, and from it he predicted that the earth must be flattened at the poles, and bulged out at the equator; and Laplace calculated the difference of the two diameters upon the same theory; actual observation has since found that both predictions were right. The predictions of astronomy are familiar to every one, and the occurrence of eclipses, and the return of comets, true to their path, and exact to their hour, after years of absence beyond the range of our telescopes, have now ceased to amaze, though they can never cease to gratify, by the beautiful accordance which they exhibit between theory and facts.

There is another useful guide which often helps us to the comprehension of the great truths of Nature: this is *analogy*. When one system of events, one set of phenomena, is similar to another, we infer that the causes of these systems are also similar; and we reason analogically respecting them, and our reasonings are more or less conclusive, according as the similitude is more or less considerable. It is by analogy, for instance, that we reason regarding the conditions of distant planets; and the phenomena of light and heat present analogies which we are fond to take advantage of in framing *hypotheses*, or suppositions, respecting their nature. Our observation of the system of nature is necessarily meagre: we are confined to a point of the great works of creation; it is, therefore, only by analogical reasoning on the little we have examined, and the small portions of the great plan which we have been able to comprehend, that we are enabled to raise our conceptions to other parts of the incomprehensible whole. It is, moreover, by analogy that we are often guided to experiment, to which the ultimate appeal must always be made; and it often serves to suggest and limit hypotheses and other conditional speculations, which usually precede the discovery of the real laws and true theory of phenomena.

These remarks point out not only the way in which successful investigations of discovery are conducted, but likewise the method by which the discoveries already made are successfully studied. The method, indeed, is essentially the same in both cases, with the exception, that the student has a guide, and arrives at his conclusion, usually by a shorter and an easier path. But whoever would comprehend any physical fact—and a theory is only a general fact—must not be content with the naked statement of a result; he must know how that result is obtained, otherwise he cannot be said to comprehend it. There is, besides, a pleasure—a pure, unalloyed pleasure —in following out the discovery of Nature's great truths, from the first feeble glimmerings which we perceive of them among the facts of our own little experience, to their formal development—from the lowest presumption, to the highest moral certainty: and this can only be obtained by pursuing a course coinciding, in many points, with that which led to the original discovery. The method has again its direct utility. The habits of observation and reflection which it encourages, besides their influence on adjunct studies, lead to a more thorough comprehension of the value of the great principles of physical science, and their applicability to the active business of life. The continual appeals which it makes to experiment, and to calculations founded on experiment, are, moreover, the best security that a just value will be set on those hypotheses, which some of the departments of science must still submit to recognise.

## NATURAL PHILOSOPHY.

### CHAPTER I.

If it be true, that the talents and virtues of an individual determine, in a great measure, the amount of his influence in society, and the sum of his rational enjoyments, it is of paramount importance to inquire how these talents are to be directed, that an object so desirable may be fully realized, and what actions are most likely to secure an increase of happiness. If our talents are not under the control of specific rules, and if our conduct does not originate in proper principles, experience plainly teaches us that we will, in all our inquiries and actions, be involved in endless errors and absurdities; and hence the end contemplated in education should be, to propound such principles as shall enable us to use our talents to the best advantage, and to direct our attention to those studies by which they will be most efficiently invigorated and matured, so that we may be prepared for entering upon the business of life in a way creditable to our rational and intelligent natures. The natural sciences, which propose to realize these important objects, present so extensive a field of inquiry, that the limited faculties of a single individual are altogether inadequate for the full development of its rich resources; consequently, a division of labour is indispensable for its successful cultivation. The division which naturally suggests itself to every reflecting individual, is that which originates in the intercourse which is maintained through the agency of the senses, between the intellectual principle within us, and the material existences without—between the world of mind and the world of matter; each of these has been farther divided and subdivided, as the principles have been more fully

developed and applied, influenced, no doubt, by the peculiar views of those who have studied them. Mental philosophy, including the science of morals, communicates to man the most important of all knowledge, namely, that which has reference to the subtile and complex machinery of the mind. It exhibits in all their purity and beauty, the principles of honour and virtue; tells man his duty, admonishes him to be just in his transactions with others, demonstrates that conduct based on proper principles procures true happiness, shows him the loveliness of virtue and the odiousness of vice, the beauty of benevolence and the distorted features of envy; changes opinions, if false, and by an easy gradation conducts to reason, calms the turbulence of passion, and awakens generous and benevolent sentiments, settles private quarrels, and removes political animosities without the sacrifice of human life; in short, makes man acquainted with himself, his obligations to his God, and the social relations which bind him to his fellow-men. But, at the same time that this division of natural science presents to our view an analysis of the phenomena of the mind, and the principles which ought to regulate human action, it likewise furnishes the student with simple and elegant methods, by which to communicate his ideas to the minds of others. It may be said of the successful student, as was beautifully said of Ulysses' oratory, that "not only the thoughts fell thick and pure as the winter's snows, but the words also."

Not only, however, does this study furnish the student with the best methods of communicating his ideas to others, it also furnishes the tests by which he may detect a fallacy in argument, however carefully concealed under the plausible hypotheses of a specious sophistry, or enforced by the harmonious flow of a graceful and persuasive oratory; enables him to divest it of its varied figures, its analogies and metaphors apparently appropriate, and to consider the whole as supposition and inference, premises and conclusion, and to judge of it accordingly. Again, although mind and matter are essentially different, nevertheless they are so intimately connected, that the powers of the former owe their development to their intercourse with the laws which regulate the latter. "Without external nature reason there would be *none*, where there would be no *data;* memory *none*, where nothing had been *perceived;* imagination *none*, where there was no *reality;*" and thus the materials acted upon unfold and perfect by a reflex influence, the instrument which, by a power almost creative, renders these materials, in their various modifications and combinations, so beneficial to the human family.

The science of matter, or natural philosophy, as it is more commonly designated, (and which we have seen is so intimately connected with mental science,) considers the properties of natural bodies, and their mutual action and dependence upon each other; and the end proposed by the cultivation of the science is, to enable man to contemplate, more fully and satisfactorily than he could otherwise do, the mechanism of the universe; and to make nature and art subservient to the necessities and conveniences of life, by skilfully connecting causes which will produce the most beneficial effects—this department is subdivided into two parts, viz., chemistry and physics, or natural philosophy used in a more limited sense. The former, by analysis or decomposition, ascertains what elementary substances constitute compound bodies; by composition, what bodies will result from the combination of particular elementary substances; it investigates and illustrates the laws by which such combinations take place, and states the results. The latter, (with which we have more immediately to do at present,) neglects entirely the composition and decomposition of bodies; it enters not into those secret recesses, where, by interesting combinations of two or more of fifty-four different substances, nature exhibits, in all their charming variety and beauty, the interesting objects around us; it has to do with laws which are, in most cases, more palpable to the senses, more general in their operation, and fewer in number. The chemist, retired from the world, elaborates, in the privacy of his chamber, by many curious and ingenious processes the principles of his science; the natural philosopher gathers his information from the more comprehensive operations of nature; and in the ascending vapour, the whistling winds, the rolling ocean, the flowing stream, the placid lake, the pendant dew-drop, the falling apple, the cheering sunbeam, and other interesting phenomena, he perceives a delightful exemplification of those laws, which, as a philosopher, he proposes to investigate. It is true, that the operations of nature, in their complex state, are varied to an extent that no language could express, and no memory retain; nevertheless, when these have been successfully analyzed, such resemblances are observed as enable the philosopher to arrange the whole under a few general heads; and, as detected resemblances naturally suggest the idea of a presiding influence, through whose agency the harmony is maintained, he endeavours, by carefully reviewing his own observations, and the observations of others, or it may be, by subjecting the phenomena when possible to the test of experiment, and the unerring principles of abstract science, to ascertain the nature of this presiding influence, and when successful in his demonstrations, he denominates it a law of nature; and, exploring in this way the extensive and luxuriant fields of the physical economy, a system of truths is obtained, most harmonious in all its parts, interesting in its details, and useful in the practical application of its principles.

While the principles of physics provide subjects of the highest interest to the philosopher,—while he, as discovery follows discovery, desires "to pierce farther and farther into the mysteries of nature, and to drink deeper and deeper at the fountain of Divine benevolence and wisdom, for which the taste already obtained has given him so keen a relish;" to the practical man, and society in general, they have a more interesting and imposing aspect, as they are perceived to bear directly or indirectly upon the business of human life; it is to be regretted that the merely practical men are so utilitarian in their views of science, as to believe that every man's experience is sufficient to instruct him in what is practical and useful, and that the inquiries of the mere theorist are of minor importance, while the very reverse is undoubtedly the case; for it is quite plain that there cannot be a practical result without a fundamental principle,—it must be admitted, indeed, that many discoveries have been made, which apparently have little or no connexion with the useful arts; but although the present generation of practical men do not perceive their application, this is no demonstration that they shall not be practically applied, as the field of their operation is enlarged. What splendid revelations, for instance, were made regarding the mechanism of the heavens, in Egypt, Arabia, and Greece, which were considered in those days too refined for the grossness of material contact, but which embolden the mariner, at the present period, to trust his little bark on the trackless bosom of the ocean, and the traveller to track his course through the uniform wastes of the desert with the utmost confidence and security—how many affinities and relations are observed by the chemist in the interesting economy of matter, which are slowly, but surely, producing momentous changes that have never yet been practically applied! It is extremely foolish and unphilosophical to conclude, because the practical application of a discovery is not immediately perceived, that, therefore, it ought to be abandoned: we know that nothing has been made in vain; for the Great Architect, as the different parts of this fair creation came into existence, pronounced "all to be very good;" the perfect adaptation of the principles with which we are familiar, the nice adjustment of the different parts of physics for the accomplishing of the different objects to which they are applied, should lead us, by a most rational induction, to the conclusion, that those principles, more recently discovered, must serve some useful end, however ignorant we may be of the mode in which they are to be applied! Grant me, for the sake of illustration, that we could see realized what was once believed of the just: that they should be again restored to earth, to witness the effects of their benevolence upon the generations which had succeeded their own times. Grant me that Thales of Miletus, and Archimedes of Syracuse, are at this moment restored to existence, and that they are beginning to contrast the state of human knowledge, and the practical application of that knowledge in their own and the present age; what would be the astonishment of Thales to find that those celestial phenomena, which served only for subjects of curious inquiry and learned disputation in the ancient schools of science, have enabled the inhabitants of continents the most remote, to minister to one another's comfort and enjoyment! How would Archimedes be delighted, as he examined the complicated machinery of our factories, and the beautiful texture of the manufactured article, when he perceived that the whole of the complicated mechanism could be reduced to the simple mechanic powers which he was privileged to point out and demonstrate! The mere practical man would, in all probability, like the nobleman "whom the prophet bade wash in the Jordan and be clean,"

consider such simple principles altogether inadequate for the full elucidation of the complex operations, by whose agency such results had been realized; it is not so with Archimedes—he rejoices to find that those simple principles, a bar of iron resting on a pivot, and a regular declivity or inclined plane, has been so extensively applied, and so generally useful.

To expect that, in every instance, the full import and application of a discovery should be immediately perceived, would require the possession of higher faculties than have ever been enjoyed, even by the loftiest intellects that have graced the walks of philosophy. "Perfection," says the poet, "is too fair a flower to blossom in such a world as ours;" and hence it is, that many of those discoveries in physics, which are of the greatest importance to man in his present circumstances, have only been applied in all their extent of usefulness, after minute, and often repeated examination. Towards the end of the sixteenth and the beginning of the seventeenth centuries, chemistry, (if it then deserved the name,) in the hands of the alchemists, consisted, in a great measure, of hypothetical absurdities, having reference to imaginary blessings; between 1640 and 1660, it received a great impetus from the pneumatic discoveries of Torricelli and Pascal—discoveries which have been the means of carrying this department of natural science forward in the path of improvement, with a velocity never before experienced—and although in other sciences the advancement has not been so rapid and continuous, nevertheless, in all of them there has been the intense application of master-minds, and the unremitting attention and deep research of experienced observers, which is abundantly evident in the inexhaustible treasures which they have discovered in the storehouses of nature. Surely, then, it is a subject of deep congratulation, to know that we live in an age, when the discovery of the first principles of many of the sciences is matter of history, and the practical application of these principles, matter of enjoyment. With a little sacrifice of time and labour, we may make ourselves well acquainted with the general facts of science—with the permanent laws by which the Almighty Creator of all things directs the operations of nature, and the endless illustration of these laws which the universe exhibits. What rich and varied sources of instruction, for instance, are contained in the changes of the seasons, the beautiful adaptation of spring, summer, autumn, and winter, to the constitution of the globe, and the circumstances of its numerous productions and inhabitants—the atmosphere, with its influence upon animal and vegetable life—the deposition of dew with its invigorating tendency—the flow of rivers to the sea, which purify and refresh the valleys through which they flow, and other phenomena,—all of which furnish subjects of instructive reflection, and deepen and elevate our ideas of the power, the wisdom, and the goodness of Him, "who said, and it was done; who commanded, and all things stood fast!"

Interesting, however, as natural phenomena are, in so far as they exemplify general laws, they become still more so to mankind in general, when viewed in their practical application to the modern arts, more particularly such of them as have a direct influence upon our comforts and enjoyments—from mechanical science we have received those machines, through whose agency we are enabled to convert wool, cotton, and flax, into warm and comfortable clothing—from chemistry, those substances by which we can beautify the manufactured article with fruits and flowers in all seasons. Mechanical science enabled Earnshaw and Arkwright to convert the distaff into the spinning-jenny, a machine of such exquisitely delicate construction, as enabled Mr John Pollard of Manchester, in 1790, to convert one pound of cotton into a thread one hundred and thirty-two miles in length. From chemistry and mechanics combined, we have received the steam-engine, which is now employed in almost every department of human industry. Take one illustration of its power. Herodotus informs us, that one hundred thousand men were employed for twenty years in building the large pyramid of Egypt, leaving out of view the workmen employed in hewing the stones, and conveying them to the spot where it was erected.* The steam-engines of England would raise the stones to a height equal to that of the pyramid, in eighteen hours, requiring the services of only about thirty thousand individuals. The illustrations of the advantages of mechanical science, indeed, are so numerous, that they must be reserved to a future number, such as the improvements which have been made in the manufacture of hosiery, from the four needles, used by

> "The knitters in the sun,
> And the fair maids who wove their thread with bones,"

and the complex machinery of the stocking-frame, and many others which will be fully considered in connexion with the principles on which they depend.

Now, although all that has been stated regarding the importance of Natural Philosophy, in these introductory remarks, may be readily admitted, nevertheless, the mechanic and artizan may naturally ask, what advantages *they* can derive from such inquiries, whose time is wholly devoted to manual labour. In answer, it may simply be stated, that if there be one class in society to whom a knowledge of the principles of natural science is of more importance than another, it is the class composed of those who cultivate the more useful arts. The mechanic is situated on the very threshold of practical science; to him is intrusted the important duty of rendering useful what science has unfolded. Cicero, the prince of Roman orators, remarks, "that every step the traveller takes in Greece, he treads upon a history of patriotism and philosophy;" so with equal propriety may it be said of the artizan, that every step which he takes in his employment, he treads upon the principles of natural science: what, then, so necessary as to make him acquainted with those principles; what so important as to have them brought before his mind so that he may understand them and appreciate their value! How would ingenuity be elicited, habits of industry be acquired, and the honest and intelligent mechanic taught to aspire to an honourable independency—to that ascendancy over adverse circumstances which is the never-failing companion of superior intelligence, and the reward of personal industry. "In such men," says Dugald Stewart, "what an accession is gained to their most refined pleasures, what enchantments are added to their most ordinary perception! The mind, awakening as it were from a trance into a new existence, becomes habituated to the most interesting aspects of life and nature; the intellectual eye is purged of its film, and things the most familiar and unnoticed disclose charms invisible before; the same objects and events which were lately beheld with indifference, occupy now all the capacities and powers of the soul, the contrast between the present and the past serving only to enhance and endear so unlooked for an acquisition." "How different," says Addison, "is the view of past life in the man who has grown old in knowledge and wisdom, from that of him who has grown old in ignorance and folly! the latter is like the owner of a barren country, that fills his eye with the prospect of naked hills and plains which produce nothing either profitable or ornamental, the former beholds a beautiful and spacious landscape, divided into delightful gardens, green meadows, and fruitful fields, and can scarce cast his eye on a single spot of his possessions that is not covered with some beautiful plant and flower."

* When Mr. Bolton waited upon George the Third, to explain one of the great improvements of the steam-engine which they had effected; the King said to him, "What do you *sell*, Mr. Bolton?" The honest engineer answered, "What kings, Sire, are all fond of—*power*."

# CHEMISTRY.

## CHAPTER I.

MAN'S RELATION TO THE MATERIAL WORLD—INDUCEMENTS TO ACQUIRE KNOWLEDGE OF NATURAL OBJECTS—BENEFIT OF CLASSIFICATION—KINGDOMS OF NATURE—GENERAL PHYSICS—MECHANICAL PHILOSOPHY—CHEMISTRY DEFINED—ULTIMATE CONSTITUTION OF BODIES—PRIMITIVE PARTICLES OR ATOMS—DIVISIBILITY OF MATTER—ATTRACTION—MODIFICATIONS OF ATTRACTION, GRAVITY, COHESION, CHEMICAL AFFINITY—ILLUSTRATIONS OF CHEMICAL ATTRACTION OR AFFINITY—SIMPLE AND COMPOUND BODIES—CHEMICAL COMBINATION—DECOMPOSITION—MECHANICAL MIXTURE AND CHEMICAL COMBINATION CONTRASTED—DEFINITE PROPORTIONS—ANTAGONISM OF COHESION AND AFFINITY—APPLICATIONS AND APPLICABILITY OF CHEMISTRY TO THE ARTS AND MANUFACTURES—CONNEXION WITH NATURAL PHENOMENA—AN AGREEABLE AND EASY STUDY—HISTORICAL NOTICE OF THE EARLY STATE OF THE SCIENCE.

1. The situation of man on the globe he inhabits is one of intense interest. A creature of boundless desires and wants

endowed with intelligence, and with the means of carrying on an active intercourse with the vast assemblage of objects around him, he feels himself impelled by necessity, and animated by curiosity, to a life of physical and mental activity. So constituted as never to feel entire satisfaction from anything he may obtain, and never destitute of the hope of some enjoyment, or free from the dread of some suffering, he is perpetually and irresistibly urged onwards by new sensations. He thus, unavoidably, becomes both intellectually and physically great, and that because his wants and his desires *are* boundless. Contemplating the vast resources with which nature has provided him, and feeling his dependence on his ingenuity to render them subservient to his purposes, he sets himself to the acquisition of a knowledge of the properties and uses of external things, and the forces inherent in them. He speedily discovers that there his power resides, and from that moment takes his rank as "the undisputed lord of the creation."

2. The vast range of external nature which we are called upon to study presents various fields of inquiry, according to the point of view in which the almost infinity of objects is considered. Convenience, moreover, and our limited powers of recollection—and perhaps also our limited time—render it necessary that we should divide our forces, appointing some to observe, others to experiment, and reserving some to measure and calculate. This division of labour has been attended with a degree of success, which it is useful to consider, as it points out forcibly the progressive nature of physical knowledge, and the relations and importance of its different branches.

3. Reviewing the steps by which our progress has been attained, it is no difficult matter to suppose, that life, being the most important of all the properties of bodies, and the highest of all characters, would at once be seized upon as a grand principle of distinction, and that all natural beings would thenceforth be separated into two immense divisions—the *living* and the *inanimate.* But active observation would speedily discover among the objects in these divisions, that there were many resemblances, and that the multitude was, in fact, "only a repetition of a certain number of kinds. Among animals, for instance, would be distinguished the horse, the dog, the sheep; among plants, the oak, the beech, the pine; among minerals, lime, flint, the metals, and so forth. And becoming aware, that by studying an exemplar of each kind, a tolerably correct knowledge of the whole might be obtained, without overtasking the powers of memory; while this knowledge could enable the possessors more easily to obtain what was useful to them, and to avoid what was hurtful; the desire for such knowledge must have arisen with the first exercise of reason. Accordingly, the pursuit of it has been unremitting, and the labour of ages has at last nearly completed an arrangement of the constituent materials of the physical world, under three great classes, *Minerals, Vegetables,* and *Animals,* commonly called the *three kingdoms of Nature,* and of which a minute description is termed *Natural History.* But while men were examining the forms, and other qualities of bodies around them, they could not avoid noticing also the *motions* or changes going on among bodies; and here too they would soon make the grand discovery, that there were resemblances in the multitude. Self-interest, as in the case of the bodies themselves, having prompted to careful classification, in the present day, as the result of countless observations and experiments made through a series of ages, we are enabled to say, that all the *motions,* or *changes,* or *phenomena* (words of the same meaning here,) of the universe, are merely a repetition and mixture of a few simple manners, or kinds of motion, or change, which are as constant and regular in every case, as when they produce the returns of day and night, and of the seasons."* The kinds of these motions, carefully noted, lead to the determination of certain laws, by which all changes are governed; and these laws incorporated into a system, constitute *Science,* in contradistinction to *Natural History.*

4. Natural science, then, is an account of the different changes to which bodies are subjected in performing their functions in the visible system of creation. In the great phenomena of nature, it contemplates motions which language readily expresses, but which the limited faculties of the mind can hardly comprehend. The planets—of which the earth is one—with their appurtenant moons, roll round the sun as their common centre, at distances of millions of miles, borne onward in their ever-varying yet certain courses, with velocities for which we have no comparison. Yet these motions it measures and subjects to all the rigour of calculation, giving accuracy to the sublime study of *Astronomy.*† Descending to the earth and the objects we meet with there, we find a still greater variety of sensible motions to examine and classify. Here matter is presented to our notice in three very different conditions—in the solid, in the liquid, and in the gaseous form. Of these, stones and most metals, water and air are examples, and the code of laws which relate to their sensible motions, constitutes *Natural,* or more strictly, *Mechanical Philosophy.* This, however, we distinguish according as it contemplates solids, liquids, or airs, into *Mechanics, Hydrostatics,* or *Hydraulics,* and *Pneumatics.*

5. "Had there been only one kind of substance or matter in the universe, mechanical philosophy would have explained all the phenomena; but there are *iron,* and *sulphur,* and *charcoal,* and fifty-two others, which appear essentially distinct. These, taken singly, obey the laws of physics; but when two or more of them are placed in contact under certain circumstances, they exhibit a new order of phenomena. Iron and sulphur, for instance, brought together and heated, disappear as individuals, and unite into a yellow metallic mass, which in most of its properties is unlike to either;—under other new circumstances the two substances again separate, and assume their original forms." Similarly, when copper and zinc *(spelter)* are fused together, both of these metals lose their distinctive characters, and the product is *brass.* By certain other processes, these metals may again be separated, and exhibited unaltered in any of their qualities, and without diminution of their quantity. Such changes are called *chemical,* and the code of observed facts relating to them constitutes *Chemistry.*‡

6. Chemistry, then, may be regarded negatively as that department of natural science, or general physics, which takes cognizance of all those changes in natural bodies, which are *not* accompanied by *sensible* motions. Its investigations are confined to the determination of the *ultimate constitution* of bodies, and the properties of the *ultimate materials* of which they are composed. In its nature and objects it is thus obviously distinct from mechanical philosophy, which surveys masses, and calculates distances, taking cognizance only of those physical actions which produce no real change in the properties of the bodies operated upon.

7. What, it may be asked, is meant by the *ultimate constitution* and *ultimate materials* of bodies? Although the question is necessary to an accurate conception of the nature of chemical science, it is not susceptible of a direct answer, and indeed, in their strict meaning, the words imply more than human knowledge will ever be competent positively to answer. That the visible universe is built up of very minute *particles* called matter, is readily admitted from common observation; but when we begin to seek for the ultimate divisions or *atoms,*‖ our limits of observation are soon passed and the imagination itself becomes lost in the pursuit. Numerous illustrations of this, both of a mechanical and chemical nature, might be adduced. For instance, every one has remarked the thinness of gold-leaf, the gilding on threads for embroidery, or indeed the coating of gold on any gilded article. Few have not observed, when amusing themselves in boyhood with making soap-bubbles, the beautiful play of colours upon the top of the bubble a little before bursting: this play of colours, arising from certain properties of light explained in optics, enabled Sir I. Newton to show by calculation, that the bubble before it bursts reaches an attenuation of at least the four-millionth part of an inch. The blood which runs in our veins, when examined by the microscope, is seen to be composed of a transparent colourless liquid called *serum,* and certain minute *globules* which float in it, and give it colour. These globules vary in diameter, from the two-thousandth to the four-thousandth part of an inch. They are, moreover, *gelatinous masses,* a circumstance which proves that they are composed of *many,* it may be *innumerable,* atoms. Besides, "there are creatures so small, yet visible by the aid of microscopes, that their whole living organization might be included in the bulk of one globule of

* Arnott's Physics.

† Properly, a branch of Mechanics.

‡ The term *Chemistry* is derived from the Arabic *Kimia,* the occult art, from *kamai,* to conceal. The Arabians prefixed their particle *al,* answering to *the,* and made it *alkimia,* which we write *alchemy.*

‖ *Atom* is from a Greek word, signifying *indivisible,* and is used to denote a particle, not susceptible of further division.

human blood; limbs for motion, for defence, and to provide themselves with food; organs of sense and deglutition; sinews, muscles, nerves; nay a circulating medium—*blood* composed of serum, and having its own globules of blood." And if the imagination can form a conception of the minuteness of such organizations, it may try to form a notion of the particles of which the fabrics are constructed.

8. Many common chemical experiments afford, however, even still better illustrations of the inconceivable minuteness of the ultimate atoms of matter. If a grain of copper be dissolved in nitric acid *(aqua-fortis)*, and added to a quart of water, a solution will be obtained which is sensibly coloured blue. The copper must therefore be diffused throughout the whole, and indeed is readily detected in the hundredth part of a grain of the solution. Now, the quart of water weighs 14,500 grains: it consequently follows, that a particle of the colouring matter is less than the 1,450,000th part of a grain. But this is not all. Whatever may be the size or weight of the ultimate atoms of matter, we know from circumstances which will be hereafter explained, that every atom of the colouring matter of this solution is made up of two atoms, one of copper, and one of nitric acid, and further, that every atom of the nitric acid is composed of six atoms of matter. We might therefore, perhaps, multiply the 1,450,000 by 7, for the weight of the atom of our copper. But our experiment needs no such refinement in calculation. Let the hundredth part of a grain of the solution spoken of, be placed on a clean iron surface, as the blade of a penknife; the copper will adhere to it in its metallic state, and it will at once be seen that the particle of liquid, instead of containing only one atom of the copper as was assumed, contains many—more indeed than the experimenter will find means to determine.

9. All attempts then to imbody a conception of the sizes or weights of the primitive particles, or atoms of matter, are futile: they are wholly beyond the cognizance of our senses. And, indeed, the apparently interminable subdivision to which a mass may be subjected, and the inconceivable minuteness at which it terminates, has led many to believe that matter is *infinitely* divisible, and some to doubt the existence of matter altogether. We leave common observation and experience to answer the sceptics, but the notion of infinite divisibility deserves notice.

10. Abstractly, matter *does* seem to us infinitely divisible, for we can never conceive of any material body so small as not to have some aliquot part, as a half or a quarter. And as the half of a material particle must be material, we cannot imagine it as incapable of a separate existence; and perplexing as the idea of infinite divisibility may appear, the supposition of an ultimate particle without parts, and incapable of reduction to smaller particles, is altogether inadmissible. But although this holds in theory, and may be demonstrated mathematically of a line at a surface, numerous facts of chemistry, while they show the inconceivable extent of the division, all but demonstrate that it has a limit, and that every body is composed of particles of a shape which in all the changes which a body may be made to undergo, are never altered in figure, or reduced to smaller particles.* This was the conception which presented itself to the comprehensive but humble mind of Sir Isaac Newton. "It seems to me probable," says he, after contemplating some chemical phenomena, "that God in the beginning formed *matter* in solid, massy, hard, impenetrable, moveable particles, of such sizes and figures, and with such other properties, and in such proportion to space, as most conduced to the end for which he formed them; and that those primitive particles, being solids, are incomparably harder than any porous bodies compounded of them; even so very hard as never to wear or break in pieces; no ordinary power being able to divide what God himself made one in the first creation."

11. This is the view of the constitution of matter now generally adopted, and we cannot hope to attain a clearer conception of it. There is no fact yet known which bears against it, unless it be that the "smooth flowing of water, or the gentle breathing of the air," would rather seem to indicate a corresponding softness in the ultimate particles, than an absolute degree of hardness and impenetrability. If, however, we take a portion of water in a glass tube, which has been carefully freed from air by boiling, and afterwards hermetically sealed, we find upon shaking it that the particles strike one another with a ringing sound, quite undistinguishable from that derived from the collision of metals.† The force with which airs strike is well known from the explosion of fire-arms. It is well known that the report caused by the firing of a gun is nothing more than the result of the collision of the aëriform atoms of the atmosphere rushing together into the vacuum produced in the gun-barrel by the explosion of the powder. It must also be observed, that there is a marked distinction made between the solidity of the primitive particles and that of the bodies compounded of them: the latter we assert to be *porous*, yet we seem to give but fair credit to our senses in believing that the particles of a "*solid metal*" must be in contact. But a little reflection corrects this prejudice. Many metals have their density increased, that is, their particles brought closer together by hammering and pressure; but to this there is a limit: all solids may have their particles brought closer together by cold, and to this no limit has yet been ascertained. Particles which admit of such nearer approach to each other, cannot of course be in close contact; and, therefore, a mass or assemblage of such must be *porous*.‡

12. Knowing then that any visible mass of matter is a collection of minute atoms, it may be asked by what cause they are made to cohere or cling together? The answer is, that *we do not know:* there are no hooks connecting them, no visible fastenings, and "the connexion may be broken a thousand and a thousand times by processes of nature and art, and it is ever ready to take place again; the cause being no more destroyed in any case by interruption, than the weight of a thing is destroyed by frequent lifting from the ground." But with the manner or laws of the operation of this cause we are well acquainted, and we give the cause itself a name from the phenomena it exhibits: that name is *attraction*.

13. This force which we call attraction exhibits its influence at all distances, and exists in all forms of matter. The moon, which is 240 thousand miles from the earth, attracts the water of our ocean under her, and forms what we call the tide. The sun, which is 93 millions of miles off, has a similar influence; and when the sun and the moon are in conjunction, (at new moon,) we have spring-tide. It is the same force which causes a stone to fall to the earth when left unsupported, and is in fact the source of all the sensible motions in the universe; and at the earth's surface, its measure is what we call *weight*. This attraction of bodies for one another, when manifested over sensible distances, is what is called *gravitation* or *gravity*. Astronomy is one connected demonstration that it pervades all the great bodies of the universe, and terrestrial mechanics afford a like demonstration of its universality, so far as regards our earth and the things upon it. It belongs, therefore, to mechanical philosophy to investigate and illustrate its laws under these circumstances. But one conclusion it is necessary here to state; it is this: the energy of the effect is *increased* in a certain proportion as the distance between the bodies is *diminished*, that is, the more closely the bodies approach, the more intensely is their attractive influence upon each other exerted.

14. This law explains at once the cohering together of the particles of a solid; for the atoms of which that solid is composed may be millions of times nearer to each other than any assignable distance we can name. Hence it is that two fresh cut surfaces of lead, or of caoutchouc or India-rubber, readily cohere when brought into contact. The same is indeed true of all highly polished flat surfaces; and were it not that the surfaces of bodies are in general so very rough and irregular, that when brought together they touch only in a very few of the millions of points which their surfaces exhibit, we would ever have bodies adhering or sticking together, when applied to each other.‖

* See Reid's Chemistry of Science and Art.

† Such a little apparatus is made, and goes by the name of the *water-hammer*

‡ Daniel's Introduction to Chemical Philosophy.

‖ When cohesion takes place between surfaces of similar or dissimilar bodies, it is commonly called *adhesion*. Thus the integrant particles of the glass of a mirror are held together by *cohesion*, and the silvering on the back is retained by *adhesion*. The insertion of a nail is accomplished by destroying the cohesion of the wood; its extraction, by overcoming the force of adhesion and friction together. By adhesion, glue sticks to wood, varnish to metals, and mortar to stones; and it is by the same power that water wets most things with which it comes in contact. When a small plate of glass, or the like, is brought into contact with the surface of a fluid, as mercury or water, adhesion immediately takes place between the two, and the force necessary to separate them may be readily ascertained by attaching the plate, by means of a thread, to one extremity of the beam of a balance, and adding weights in the scale-pan at the other extremity, till the plate is raised from the surface of the fluid. When the experiment is made with mercury, the weight required to raise the plate determines the amount of *adhesion* between the solid and the fluid, but when the liquid is water, the force required to lift the plate is the measure of the *cohesion* among the particles of the fluid; for a film of water will be found to attach to the plate, making it *wet:* it is the adhesion of this film to the rest of the fluid which i

15. Different kinds of matter, and matter in different states; appear, moreover, to be held together by different degrees of this cohesive force. A bar of iron, for instance, and a rod of glass, require very different degrees of force to break them. The particles of water cohere very slightly, and so do those of quicksilver at ordinary temperatures; but ice, which is solidified water, manifests cohesion in a considerable degree, and quicksilver, by being subjected to intense cold, becomes a solid and malleable metal. By the application of sufficient heat again, water and quicksilver may be converted into vapours, which exhibit no cohesion while in that state, but are influenced by an opposite force; the particles for the time repel each other; the cohesion is not only suspended, but superseded by a new power. This power we call *repulsion:* it is the antagonist of the cohesive attraction, and must therefore considerably modify its effects. It is, indeed, to the antagonism of these forces that we owe the different states of matter, for it is manifest that were there only atoms and attraction in the universe, the whole "material of creation would rush into close contact, forming one huge solid mass of stillness and death;" and on the other hand, were repulsion the predominating force, the whole material universe would disappear, and fill space with impalpable atoms. But we have *solids* formed by the predominancy (within certain limits) of cohesion, *liquids* arising from the nearly equal balance of the repelling and attracting forces; and *airs* and *vapours* result when the repulsive power predominates.*

16. The distinction then between *gravitation* and *cohesion*, or *cohesive attraction*, consists in this: the first operates between masses and at all distances, the latter binds particles together and is perceptibly exerted only at insensible and small distances. If a piece of glass fall from the hand, it is brought to the ground by the force of gravity, and it will probably be broken in pieces, because its attraction of cohesion has been overcome by the shock. If the fragments be now pounded, the powder will still be under the influence of gravity, for it would still weigh as heavily as the unbroken glass did; but it is impossible, by any known mechanical means, to bring the pounded fragments so closely together as to be within the range of each other's cohesive attraction, so that the whole shall join again into a mass. If, however, we put this powder into an iron spoon, or the like, and subject it to a high heat in a common fire, it speedily becomes a fluid by the suspension of the cohesion which held together the atomic particles in the little masses which formed the powder; and if now it be allowed to cool, cohesion again begins to act, the particles attract each other strongly, and by and by we have *a mass* of glass as solid as ever.†

17. The variety of attraction to which we give the name of *cohesion*, we have considered as acting among particles of the *same* sort of matter aggregating them together into masses of definite or indefinite forms. But there is yet another variety of the utmost importance to the chemist, and differing from cohesion in that it unites particles or atoms of *different* kinds of matter together forming *compound atoms*, aggregations of which are called *compound bodies.* This is the modification of the attractive force which presides over the composition of bodies, and produces all chemical varieties: it is therefore called *chemical attraction*, and for reasons which will appear, it is oftener named *chemical affinity*, or simply *affinity*. The nature of this power will readily be understood by a few instances of its action.

18. If a piece of lead be melted, and a bit of tin be gently laid on its surface, it floats there in the same manner as a cork would on water, because tin is lighter than lead. In a short time, the tin will melt with the heat; and being lighter, we should expect it not only to float, but to constitute the upper stratum when the two metals have grown solid by cooling. It happens, however, otherwise; for we find neither the lead nor the tin in their respective situations; both metals are perfectly blended; and a particle cut from the lump, whether top or bottom, will be found to be composed of both tin and lead. Now why in this experiment is the greater weight of the lead overcome, so that it is drawn upwards through the tin, and mixed with it at its surface? and why is the greater lightness of the tin overcome so that it is drawn through the heavier lead to the bottom? The attraction then which has so effectually blended the particles of the metals (forming the compound which we call *pewter*,) has operated in opposition to gravity, and differently from cohesion: it is an instance of *affinity*.‡

19. Affinity does not manifest itself in all cases under the same circumstances. Thus, if a rod of iron be immersed in mercury (quicksilver), no effect is produced; the rod on being taken from the mercury exhibits no appearance of having been immersed. But if a rod of gold be similarly immersed, and taken out, it will be found remarkably changed: it will be white, and covered with a coating of mercury which no mechanical force can remove; and if left long enough in the mercury, it will be soft and brittle. It will in fact be penetrated by the mercury, and any portion scraped from its surface will contain both gold and mercury. Now, why does the mercury not in the same way attach itself to and penetrate iron? why does it so readily attack gold? These questions are unanswerable in so far as the cause of attraction itself is inexplicable, and we must be content, however humiliating, with knowing the *fact*, that this variety of the attractive power, which we call *chemical*, does manifest "preferences and dislikes, or *affinities*," in its action, and to learn as much regarding it as possible.

20. The same phenomenon of preference and dislike, or affinity, is manifested between liquids. Thus, oil and spirit of wine are both lighter than water. If we cautiously pour into two glasses, each containing some water, a quantity of oil, and a quantity of spirit of wine, respectively, the oil will continue to float on the surface of the water for any length of time, it having no affinity for that liquid; but the spirit of wine, on the other hand, will speedily descend to the bottom, and be equally diffused through all parts in consequence of the affinity exerted between it and the water. This fact is known to every "spirit-dealer" and exciseman, and is taken advantage of in regulating the strength of dram spirits. These are simply solutions of alcohol (spirit of wine) in water—sometimes coloured and flavoured as gin and brandy, and sometimes pure, as whisky. What we call "proof spirit" consists of equal parts of water and alcohol, (appropriately named "parliament whisky" by George IV.)

21. Numerous experiments have further shown that chemical attraction is exerted between the atomic particles of bodies in every different degree from zero upwards. That is, of three bodies, which we may call A, B, and C, although A may have affinity for both B and C, it rarely happens that that affinity is manifested in equal intensity for both, but in different degrees of force. These degrees we have no means of ascertaining with numerical accuracy, nor indeed is it of much importance that we should. To take an instance: there are three substances in common use, soda, magnesia, and sulphuric acid (oil of vitriol.) The sulphuric acid has an affinity for both soda and magnesia, and will combine with either of them. But suppose that these three substances are mixed together, what will be the consequence? Will they all combine together and form one compound consisting of three ingredients, as would be expected from the circumstance that the sulphuric acid has an affinity for *both* of the other two? The result is different. Notwithstanding that the acid has an affinity for both soda and magnesia, one only of these affinities is obeyed: the sulphuric acid combines with the soda, and the magnesia remains unaffected. This, however, is only true when the quantity of the acid is within certain limits; but the phenomenon is not the less surprising, for even the smallest quantity of the acid might have been expected to divide itself equally between the two other bodies.

22. The knowledge of the fact here pointed out enables us to effect what is termed *decomposition.* Suppose that we still employ the same substances as in the last case, but under somewhat different conditions: suppose that the sulphuric acid and magnesia are already combined, forming the well-known substance called *Epsom salt;* and suppose that we dissolve some of this salt in water. The solution will be quite clear and transparent (if the materials are pure); but the moment a little solution of soda is poured in, the sulphuric acid of the salt will separate from the magnesia, and combine with the soda, and the

therefore broken. This, then, is an instance where adhesion is more powerful than cohesion, and one, moreover, which may be reckoned among the finest provisions for our benefit in the economy of Nature.

* This subject will be fully treated in our article on Heat.

† Such cases of the suspension and restoration of the cohesive attraction are exceedingly important, and in some of the phenomena which arise exceedingly interesting. We shall have occasion to enlarge on the causes and circumstances hereafter, especially in our article on Crystallization.

‡ Donovan's Chemistry, Cabinet Cyclopædia. A strictly similar case is the solution of a lump of sugar in a quantity of water. The sugar when thrown in sinks to the bottom; yet, after a time, it is completely dissolved, and is found diffused through all parts of the water to the very top, in consequence of affinity. All cases of the solution of solids in liquids are of the same kind.

magnesia which was formerly invisible and in a state of solution, will now appear, and will, after a time, settle to the bottom in the form of a white powder. The salt in this process is said to be *decomposed*, and the process itself is a case of *decomposition;* and farther, the falling down of the magnesia is called *precipitation*, and itself a *precipitate*.

23. Most of the great changes which are constantly taking place in nature, are instances of decomposition. It is by decomposition that the solid rock becomes covered with fertile soil; it is by the same process, that the soil throws up its verdant clothing—that growing plants are converted into animals by assimilation—that animals at length fall into decay, and return to their original state—in fine, it is by decomposition that the great natural processes of renovation and decay are kept in a state of perpetual circulation.*

24. It may be here proper to observe, that when a body cannot, *as far as known*, be decomposed into two or more ingredients, it is said to be a *simple substance;* but otherwise, it is called a *compound*, and the simple substances composing it are said to be in a state of *chemical combination*. Thus, copper is a simple substance; for all the particles we can extract from it possess exactly the same properties, and by no process yet known can it be shown to be compounded. But brass can readily be shown to be composed of copper and zinc; it is therefore a compound substance. Similarly, iron is a simple substance; for it never has yet been decomposed—but steel and cast-iron are compounds, for they are resolvable into iron and carbon (charcoal). Chemical combination, moreover, is essentially different from mechanical mixture. This merely implies the mixture of bodies, without attraction of the parts by affinity. If water be added to water, or sand to sand, the effect is an increase of quantity, but no other change is effected; the mutual action of the particles is entirely mechanical. Again, "if a blue powder and a yellow one, each perfectly dry, be mixed and well shaken together, a green powder will be produced; but this is a mere effect, arising in the eye, from the intimate mixture of the yellow and blue light, separately and independently reflected from the minute particles of each; and the proof is had by examining the mixture with a microscope, when the yellow and blue grains will be seen separate, and each quite unaltered. If the same experiment be tried with coloured liquids, which are susceptible of mixing without chemical action, a compound colour is likewise produced, but no examination with magnifiers is in that case sufficient to detect the ingredients; the reason obviously being, the excessive minuteness of the parts and their perfect intermixture, produced by agitating two liquids together. From the mixture of the two powders, extreme patience would enable any one to pick out with a magnifier grain by grain, to separate the ingredients; but when liquids are mixed, no mechanical separation is any longer practicable: the particles are so minute as to elude search. Yet this does not hinder us from regarding such a compound as still a mere mixture, and its properties are accordingly intermediate between those of the liquids mixed."† But where chemical action does take place, there is a real change, and the resulting compound differs more or less completely, in its leading characters, from any of its component parts. For instance, that useful and agreeable substance, culinary salt, which is not only harmless, but wholesome, and absolutely necessary to the well-being of man, is composed of two formidable ingredients, either of which, taken into the stomach, proves fatal to life; one of these is a metal, and the other an air or gas: the former called *sodium*, and the latter *chlorine*. Similarly, the well-known medicine, Glauber's salt, is composed of two caustic poisons; the one oil of vitriol, (sulphuric acid,) and the other soda. The air which we breathe, and which is indispensable to life, is a mechanical mixture of the same ingredients, which, when chemically united, form that most violent and destructive liquid called nitric acid (aqua-fortis). This powerful acid, by being made to act upon sugar, the sweetest of all things, produces a substance intensely bitter to the taste. Charcoal is, of all known substances, the most difficult to convert into vapour, so much so, indeed, that the conversion has never yet been decidedly effected. It is also a very solid substance, and diamond, which is nothing but crystallized charcoal, is one of the hardest bodies in nature. Sulphur, in the solid state, is also a hard substance, and to hold it in vapour requires a high temperature. But when these two substances—charcoal, or carbon and sulphur, are made to combine chemically, so as to form the substance called bisulphuret of carbon, their properties are strikingly changed. Instead of the compound being hard, it is a thin liquid, and is not known to freeze or solidify at any degree of cold that can be produced. Instead of the compound being difficult to vaporize, it is, of all liquids, one of the easiest converted into vapour. Charcoal is the blackest substance with which we are acquainted; sulphur is of a lively yellow hue, but the compound is as colourless as water.‡ Charcoal has no smell; the smell of a piece of sulphur is not peculiarly disagreeable; the smell of the compound is about the most disgusting that can be conceived. And, in fact, the compound has not one point of resemblance with its components. These facts sufficiently illustrate the distinction between mechanical mixture and chemical combination, and the changes of properties which follow from the last.

25. It is also a remarkable fact, not to be overlooked, that when different substances combine in obedience to chemical attraction, the proportions of the ingredients are always uniform, and such as lead to the conclusion, that for every atom present of one substance, there is exactly one, or two, or three, and so forth, of the other; so that if there be exactly 1000 atoms of one substance in a compound, there will be 1000, or 2000, or 3000, and so forth, of the other, and not any intermediate number, as 1300, 1700, &c.; and this is under all circumstances, whether the compound be formed by nature or art. To take an instance:—a certain number of atoms of mercury, weighing 25 grains, combine with another certain number of atoms of sulphur, weighing 2 grains, and form the black compound called Ethiops mineral, (sulphuret of mercury,) and if a little more of either ingredient be added, it lies as a foreign substance, and does not enter into combination; but if just as much sulphur be added as at first, (namely, 2 grains,) so that there may be two atoms of it instead of one, in every particle of the compound, a perfect combination of the whole will take place, forming the well-known substance, vermilion. This exactly accords with our view of the constitution of matter, and the indivisibility of atoms. If we had found the mercury and sulphur, or simple substances generally, combining in all proportions, we should then have been driven to admit something like the infinite divisibility of matter, or the palpable absurdity of the divisibility of atoms; but thus it appears, that although we do not know the exact number of atoms in a given quantity of any substance—whether, for instance, a grain of Ethiops mineral contains more or less than a million of them—still, as we know that in that grain there are just as many atoms of sulphur as of mercury, and that the weight of the whole sulphur is to that of the whole mercury as two to twenty-five, we know that the single atoms must have the same relation, or that the atom of mercury is $12\frac{1}{2}$ times as heavy as one atom of sulphur.‖ From considerations of this nature tables are formed, exhibiting the relative weights of the atoms of different substances, and the numbers which express them are called their *chemical equivalents*. Thus, if the atom of sulphur be taken as 1, the equivalent of mercury will be $12\frac{1}{2}$; but for reasons which will afterwards appear, the atom of sulphur is reckoned at 16, and therefore that of mercury must be taken at 200, (or 16 times $12\frac{1}{2}$).

26. It is also to be observed, that there is, strictly speaking, no such thing as an *atom* of a compound; for it is distinctly to be borne in mind, that by chemical combination is understood an actual uniting together of the atoms of the ingredients. Thus, if 10 atoms of zinc and 10 of copper be combined, they form 10, *and not 20 atoms* of brass. The ultimate *atom*, therefore, of a compound, must contain at least one atom of each of its ingredients, and ought, perhaps, in strictness, to be called a *molecule* (a particle composed of atoms). The distinction is, however, but rarely attended to.

27. We shall again have to recur to the doctrine of chemical attraction; but the few facts here adduced are sufficient to convey a very distinct notion of its nature, as distinguished from cohesion. This last, it will be remembered, operates between particles of the same kinds of matter, producing aggregation: affinity operates between the particles of different kinds of matter, producing out of a few elements the endless diversity of bodies which constitute, as far as has yet been explored, the mass of our globe and

* Denovan.
† Sir John Herschel's Discourse on the Study of Natural Philosophy.
‡ Denovan.
‖ Arnott's Physics.

all its furniture. Cohesion binds together the particles of copper and of tin; affinity unites the particles of these metals atom to atom, and forms of them a new metal, (bell-metal,) having some very different properties from either copper or tin. But here cohesion is also concerned; for it binds together the compound molecules of this new metal, and renders it a solid. Gravity, also, still retains its power, for the compound metal weighs just as much as did the materials of which it is compounded. Chemical attraction does not, therefore, in the slightest degree, interfere with the general attraction of gravity; but in chemical action it is the antagonist of cohesion, as cohesion is the antagonist of chemical attraction; and chemical action will, or will not ensue, according as the one or the other predominates. Thus, if a piece of the precious stone called sapphire, be thrown into oil of vitriol, (sulphuric acid,) there is no action, because the cohesive force is more powerful than the affinity exerted by the acid; but if the stone be finely pounded, the resistance of the cohesion will be much lessened, and the force of affinity becoming an over-match for it, the stone dissolves with facility. We have cited other instances, in which the force of cohesion required to be overcome by heat or solution, before affinity could operate. We might, however, have likewise stated instances where it is necessary to have recourse to exactly opposite means, in order to induce chemical combination. An air or gas manifests no cohesive force; and the distance between its particles is so great, and maintained by such a powerful repulsive agency, that there is, in many instances, considerable difficulty to be overcome, before a combination can be brought about, even where the gases presented to each other have great mutual affinity—so much so, indeed, that on lessening the distance between the particles, by compression, they combine not only with facility, but with violence. Instances of this kind will be given hereafter.

28. The illustrations already adduced, are perhaps sufficient to convey a very precise idea of the nature of those powers, or modifications of power, in matter, by which the phenomena of the material world are brought about:—of *gravity*, operating universally upon all forms of matter, and at all distances; of *cohesion*, operating only at insensible distances, and binding together the particles of which aggregate bodies, whether simple or compound, are made up, and manifesting itself also in adhesion; of *chemical attraction*, or *affinity*, operating also at insensible distances, but only between the particles of different kinds of matter, and producing all compound substances, and these differing, more or less completely, from their constituents, in some, or all of their qualities, as taste, smell, colour, form, density, fusibility, solubility, &c. They may also convey some notion of the degree of relationship which exists between chemistry and the other departments of physical science; and by bringing forward the class of actions which it belongs to chemistry to investigate, they suggest some of its numerous applications to purposes of practical utility, as well as its power to afford elucidation of many natural phenomena.

29. Indeed, from a simple announcement of the nature of chemical action, and of the subjects with which it is conversant, it is not difficult to perceive that the field which chemistry assumes to occupy is one of the most important and extensive that could be opened to human investigation. Contemplating, as it does, almost all the changes in natural objects with which we are more immediately connected, and in which we have the greatest interest, enlightening our path in our examination of Nature's works, it appeals to our attention, not merely for its own sake, "because it increases our knowledge, and gives us the noblest display of the wisdom and goodness of the Author of Nature; but because it adds to our resources, by extending our dominion over the material world, and is therefore calculated to promote our enjoyment and increase our power."

30. Most of the arts of civilized life afford proofs of this, more or less complete. Although, strictly speaking, the greater number of the arts went before the cultivation of any science, having originated in the necessities of our nature, and improved to some degree of excellence by the routine of practice, benefiting occasionally by happy accident; still their principles are dependent on science, and a knowledge of these principles is the most certain guide to their improvement, or even their successful practice. Thus, then, for his own sake, the agriculturist ought to be a chemist. There is no art more important—none so susceptible of indefinite improvement, and it is more directly connected with chemistry than any other science. The physician is by profession a chemist, and the housewife by practice; and every man ought to be able to determine whether he has not intrusted his life to the keeping of empirics, who may be able to prescribe the poison but not the antidote. The bleacher, by the application of a process purely chemical, decomposes the colouring matter of the thread, and renders it easy to remove. The dyer extracts the colours of many substances by chemical processes, brightens their brilliancy by a multitude of chemical agents, and, by the intervention of others, fixes and renders them permanent in the cloth. The brewer, by a regulation of circumstances, changes the qualities of the fermenting substance, and obtains products suited to his object; and from which the distiller, by a chemical process, can separate the "ardent spirit," in which their principal qualities reside. The soap-maker converts tallow and soda into soap, and the tanner changes hides into leather by purely chemical means. The manufacture of glass and of porcelain, and the fabrication of paper, depend upon chemistry. The metals are extracted from their ores, purified, and formed into instruments for use and for ornament, by chemical aid. In fact, it would be difficult to name an art or a manufacture which does not depend more or less on this science. Its principles seem to ramify over all—lending here the whole process, there a part; pointing out to one improvement in manipulation, and suggesting to another some useful application. It is found busying itself in combining together the most worthless materials, and thereby converting them into articles of ornament and use; and we find it descending to the commonest concerns of domestic economy, and superintending their details, and there is no instance on its records, where it has been properly appealed to and did not furnish aid.

31. As a science, it is intimately connected with all the phenomena of nature. Not a drop of rain can fall, or a flake of snow float in the air, without its permission. Not a dew-drop can glisten on a leaf, or a blast of wind blow it off, except by its laws. It guides the reins of the earthquake in its desolating course, and presides over the volcano's most dire eruption. It even explores the bowels of the earth, and lays open to us the attractions and combinations which were going on there in those ages of which geology tells. The only illustrations which the vegetation of plants have ever received, have been from its principles; and turning to our bodies, it examines the process of digestion—how it is that the heterogeneous materials of which our food consists, are converted into flesh and blood, bone and muscle. It investigates the function of respiration, and unfolds the absolute necessity of having pure air to breathe for the maintenance of health. In perspiration it discovers a function subordinate to respiration, but nearly of equal importance to the healthy action of the system. It speculates on the source of animal heat, or that power by which the healthy body preserves a uniform temperature, whatever may be the temperature of the medium in which it lives; and lastly, it examines the fluids and solids, and tells of what elements the body is composed, thereby lighting the physiologist to new researches, and the physician to many practical applications of his knowledge.

32. Notwithstanding the almost boundless range of this science, and the inherent complexity of its inquiries—the infinite multitude of causes which are concerned in the production of even the simplest case of chemical phenomena—there is no branch of human investigation which may be cultivated with more, or even equal success, by every person possessing ordinary intelligence and industry, or in which so great an amount of real knowledge can be acquired on equally easy terms. It is indeed true, that the very highest order of intellect may be necessary to make a discovery, but when once made, the meanest capacity is qualified to comprehend it. The discovery that water is composed of two gases, was an era in chemistry, and for a time engrossed the attention and exercised the ingenuity of the best minds in Europe; but once known, there is no more difficulty in comprehending the fact, than there is of understanding the circumstances concerned in the rusting of a piece of iron. The science is completely an experimental one; and even the theories which it involves are for the most part of that generally intelligible and readily applicable kind, which demand no intense concentration of thought, and lead to no profound mathematical researches. The simple process of inductive generalization, grounded on the examination of numerous facts, all of them presenting considerable intrinsic interest, has sufficed, in most instances, to lead by a clear

and direct road to its highest laws yet known.* It requires not the practice necessary to follow successfully a process of abstract reasoning; it requires only experience and active observation—a patient attention to phenomena as they arise, and ingenuity enough to cross-examine our witnesses while offering their evidence under the hands of the experimenter.

33. It may be expected that we should here furnish some brief outline of the history of a science which is so important to man in his civilized state. The subject is certainly one of great practical interest, as above all others it affords the clearest insight into the efforts of man's speculative nature, and enables us to trace his steps towards the discovery of truth, through a series of mistakes, failures, and fallacies. But the real history of chemistry is chemistry itself, and can only be thoroughly comprehended when its facts are known. From its very nature it is a progressive science, and as a real science it is peculiarly of modern origin. It formed no part in the philosophy of Greece and Rome. The doctrine of the four elements—the hypothesis that all matter and material things are made up of fire, air, earth, and water—was the absurdity taught by the disciples of Aristotle and Galen, and which held undisputed sway over Gentile, Christian, and Mohammedan, for fifteen hundred years.† Alchemy arose, and was a step in chemistry, in so far as it recognised the use of the cupel and retort, and appealed to experiment; but how perverted were the forms, how perplexing the speculations, and how mixed up with mysterious follies and extravagancies! Its objects were to make gold, and prepare an elixir of life—a medicine which should render man immortal! The principles laid down were, 1st, that the substances which compose gold exist in all metals, contaminated indeed with various impurities, but capable by a proper purification of being brought to a perfect state; and 2d, as gold is indestructible, a plentiful administration of it would render the human body indestructible also. The great object of research, then, resolved itself into the means of procuring the change necessary in bodies to eliminate the gold, and consequently to convert the baser metals into that "precious one." The substance which was to effect this wonderful transmutation, was the "philosopher's stone," and many boasted they were in possession of that grand instrument. The writings regarding it are however remarkable for nothing but obscurity and absurdity. The language is studiously enigmatical, and to be understood only by adepts, and those favoured with illumination from heaven. The imposture, however, for a time gained implicit credit, and rendered the covetous dupes to the tricks of a fraternity of knaves, who, under pretence of communicating a secret which was to enrich the possessor beyond measure, generally left ruin where they had found a frugal plenty. Their attempts upon the credulous invalid were not less successful. The philosopher's stone itself was ultimately asserted to be an instantaneous remedy for every known malady to which human nature is subject. Even to such an extent had this delusion attained, that the highest order of intellect in the world was enlisted in its defence. The good and great Roger Bacon, who lived in the thirteenth century, affirms that an alchemist of the name of Artephius died in his time, after having prolonged his life by the miraculous force of his medicine, to the good old age of one thousand and twenty-five years. Unfortunately, however, for the credit of this worthy old man, history has been pleased to fix the date at which the first European alchemist lived, as late as the tenth century, and its rise in Arabia at no earlier a period than the fifth. We find also Paracelsus, a distinguished alchemist, himself boasting that he could live as long as he thought proper. However, he appears to have soon become tired of life; for he died at the comparatively early age of 47—not, however, before he had run through a complete career of absurdity and debauchery. One good however he did: he carried his speculations regarding the philosopher's stone and the universal medicine to the utmost height of absurdity, and by exemplifying in his own person their utter worthlessness, he contributed more perhaps than any other man to their overthrow and disgrace. The death of Van Helmont, the last great specimen of the sect, completed their downfall, and the dawn of reason began to rise. The darkness of the dark ages was then beginning to break. The scholastic system of philosophy—a singular combination of subtilty and absurdity—began to decline and a philosophy more rational in its principles, and more useful in its objects began to rise on its ruins. Chemistry participated in the revolution, and its cultivators, instead of trying to make gold, and to prepare a medicine which should inflict immortality on beings of care, began to apply their knowledge to real advantage. Beecher published his Subterranean Physics *(Physica Subterranea)*, at Frankfort, in 1669; and although the book contained absurd theories, it formed an era in the history of the science from which we are to date its true progress. Chemistry had escaped for ever from the trammels of alchemy, and it passed slowly onwards, till, in 1786, it was taken by the hand by the famous Lavoisier, and placed in the "rank of one of the exact sciences—a science of number, weight, and measure." Such we will consider it in our next chapter

* Herschel.

† Whewell's History. It is a singular fact that this nonsense is still found in our dictionaries as the definition of *element*. The term element is used in chemistry in the same sense as simple body.

# MATHEMATICS.

## INTRODUCTORY REMARKS.

Every one in commencing the study of Mathematics, soon discovers that it is of a very different nature from all those with which he has been accustomed. All the previous pursuits with which the mind could have been engaged, want much of the precision, and offer nothing of the absolute certainty of mathematical demonstration. What, for instance, are the claims of historical facts to the belief which they obtain? On what do we rest our assent to the truth of an event of which we have not ocular evidence? The ready answer is, that we have no absolute certainty, and that we are content to rest our belief upon probability alone. We have the relation of historians—of men of credit, who lived and published their accounts during the lifetime of many competent witnesses of the event narrated. We weigh the circumstantial evidence adduced—consider the facilities which the writers had of acquiring accurate information regarding the event, the credibility of these writers, and the likelihood that any material error of the narrative would have been detected and exposed by other contemporary authors—we consider all these, and finally the consistency of the fact with human experience, and finding them all satisfactory to our judgment, regard ourselves justified in giving our assent, or rather indeed, "the mind is so constituted, that upon a knowledge of all these arguments, we cannot help believing in spite of ourselves." Take a fact—the assassination of Cæsar by Brutus and his friends, for instance:—we believe that such an event did happen, 1st, because it is well attested, and 2d, because there is nothing improbable that a successful adventurer should meet with his death in the way described. But still it is not impossible that the whole narrative may be false, and all that the best management of the evidence can accomplish is, to show that its truth is extremely probable, and the falsehood extremely improbable. In mathematics the case is wholly different. Instead of showing that the contrary of a proposition announced is improbable, we prove at once that it is absurd and impossible.

It may be inquired—How is this done? What is the foundation of our mathematical certainty? The answer is this: The demonstration is strictly logical—rests nothing on probability, and is entirely independent of authority and opinion. The arguments rest upon truths, which are self-evident—they command our assent as soon as they are comprehended. These first principles are what we term *axioms*, and as an instance we cite the following:—"*If a magnitude be divided into parts, the whole is greater than any one of those parts;*" or more shortly, "*A whole is greater than its part.*" Such a truism cannot be made clearer by any amount of explanation, than it appears from its simple enunciation. And should any doubt arise, our eyes and hands furnish the means of making the truth even more palpable. But the common objection urged by the beginner in mathematics, is of a totally different kind. He feels himself humbled by being supposed to want such elementary information, and it is with some difficulty that he brings down the mind to

the low level of "beginning at the beginning." He forgets in his pride, that the "lowest steps of the ladder are as useful as the highest," and he perhaps forbears to reflect, that these very simple truths evince no mean degree of superiority in the mind which first imbodied them, and laid them down as the basis of a system of reasoning, which has grown to be the most exalted which the intellect of man has ever raised.

Another reason for the certainty of mathematical demonstration is, that every term employed is distinctly explained, and has but one meaning: "There are no words whose meanings are so much alike, that the ideas which they stand for may be confounded. Between the meanings of terms there is no distinction, except a total distinction, and all adverbs and adjectives, expressing difference of degrees are avoided. Thus it may be necessary to say, 'A is greater than B,' but it is entirely unimportant whether it is very little, or very much greater than B. Any proposition which includes the foregoing assertion, will prove its conclusion generally; that is, for all cases in which it is greater than B, whether the difference be great or little."—*Study of Mathematics.*

As a discipline of the mind, mathematics offers particular advantages. Reasoning is an art which must be learned. We cannot fence, or swim, before we have learned these arts; and it would be equally preposterous to expect a full development of the reasoning capabilities, without due training of the mental powers. Now, in order to learn to reason, it is necessary to have something to reason upon. It does not, indeed, signify much, what subject is chosen, provided it can be reasoned upon with confidence. But the reasoning of mathematics is not only logical, but also leads to conclusions, which can always be verified; that is, their truth or falsehood can always be ascertained by other means—in geometry, by actual measurement, and in algebra, by common arithmetical calculation. This gives confidence. If our conclusion is false, we can readily retrace our steps, and retrieve our error. Reason becomes thereby the pupil, not the instructor.

As a key to the attainment of other sciences, the value of the mathematics is too well known to render it necessary to make any remark on that head. It is not, however, in mechanical philosophy, and the higher branches of physics only, that their influence is felt. They appear in the workshop, and in the very humblest walks of everyday life. The proper thickness of an ordinary wall is a subject of mathematical calculation, and so is that of the hoops of a brewer's stock-tun. Everybody allows that a bridge should be constructed on the best possible principles, for strength, elegance, and cheapness—such principles are only explained by the higher mathematics. The construction of a mill-dam is reckoned an undertaking almost beneath the notice of the regular civil engineer—yet the efficient construction, even of this simple work, can only be effected by a strict attention to mathematical principles. A steam-engine is now a common piece of mechanism—yet some knowledge of mathematics is required to explain the parallel motion of its piston-rod, and to calculate the square inches in its steam-cylinder. In fact, every kind of structure, and all sorts of machines, involve calculation, and there is no undertaking of the architect, the civil engineer, or the general mechanic, which is not indebted to the mathematics for some element of its efficiency.

As we intend our course on this subject, to be both full and practical, and especially adapted to the wants of those who have not had the advantage of any regular system of intellectual education, we shall take it up at its commencement, and smooth the way as much as possible. We would, however, remind our younger readers, of the saying of the old mathematician—"*There is no royal road to geometry*"—and we further assure them, that this is not only true as applied to geometry—it is equally applicable to every department of mathematical knowledge, from the simplest rules of arithmetic upwards. Whoever would know must learn, and every one must learn for himself. No teacher can inject learning: his business is to point out the way, remove encumbrances which needlessly obstruct it, and render it as little rugged and toilsome as its nature will allow. But there are inherent difficulties which no human power can effectually remove, and which are to be surmounted only by real exertion. As some encouragement, however, we hold out the fullest assurance, that no one with ordinary abilities, and with a fair share of industry, has cause to fear for success. If he is but in earnest, he will succeed; and should his first efforts be discouraging, he must bear in mind, that here as in every other study, the first steps are the most toilsome. The mind, like matter, has its inertia; and like the machine, it requires an effort to make a fair start; but this once attained, the motion is maintained with comparatively slight exertion.

As the object of mathematics is the measurement or comparison of quantity, and as there are two kinds of quantity, *number* and *surface*, the science naturally divides itself between *arithmetic* and *geometry*, with their subdivisions. We begin with arithmetic.

## CHAPTER I.

### ARITHMETICAL NOTATION AND NUMERATION.

1. The first ideas of arithmetic, as well as those of other sciences, are derived from early observation. How they come into the mind it is perhaps unnecessary to inquire. The child compares objects, and finding that they differ in size, soon becomes familiar with the idea of *magnitude*. It collects together its toys, and learns the meaning of *number* and *quantity*. Yet these are terms which it is not possible to define. It is true, they may be translated—others of similar import may be substituted for them—but they are terms so simple—that is, the ideas for which they stand are so completely the first ideas of our mind, that it is impossible to find others more simple, by which we may explain them. This is what is meant by defining a term, and ought not to be attempted where the explanation must be harder than the term explained.*

2. To express the magnitude of a thing, or collection of things, which are all of the same kind, by means of language, so as to convey a precise idea of it to others, we fix upon some portion of that kind of thing, the magnitude of which portion is well known, and state how often this portion is contained in the thing or collection of things of which we speak. This portion fixed upon is called a *unit*, and is the base of measurement for things of its kind. Thus, for instance, when we say that a log is twelve feet long, or that a bar weighs twelve pounds, we state how often the known portion of length called a foot, or the known portion of weight called a pound, is contained in the length or weight in question. In these cases then, the foot is taken as the unit of length, and the pound as the unit of weight; and the term which is used to express how many times the unit must be repeated to form a whole, equal to the magnitude spoken of, is what we denominate *number*.

3. In every particular classification of numbers, the unit is a portion taken arbitrarily, or established by usage. Sometimes, indeed, there is something in the nature of the thing whose magnitude is to be expressed, which makes us choose one unit rather than another. Thus, in stating the size of a crowd of people, of a drove of sheep, or of a fleet of ships, everybody would fix upon a single person, sheep, or ship, as the unit. But often there is nothing to indicate what portion we ought to choose as our unit. This is particularly the case with weights and measures, where the units are fixed by the community who use them, and where in consequence every nation has its own set of units, and consequently its own system of weights and measures. But it is highly desirable that those quantities fixed upon as units, should be as extensively used as possible, and especially, that all those units which bear the same name, should be identically the same. For instance, we have two sorts of units of weight, bearing the name *pound;* it is therefore necessary in stating a weight of so many pounds, to state at the same time whether the avoirdupois unit has been taken, or the troy unit, or what is equivalent, to bear in mind what sort of articles are weighed with the one and with the other. The unit also must be of the same kind as the thing measured, for there can exist no measurable relations, except between quantities of the same kind. It would, for instance, be obviously absurd, to attempt to calculate the number of yards in a bushel, or how many gallons of wine there are in a load of coals.

4. When the unit is restricted to a certain thing, in particular, as one pound, one yard, one gallon, the assemblage of many of

* *Study and Difficulties of Mathematics*, by Professor De Morgan. (*Library of Useful Knowledge.*)

these units is called a *concrete* number, as *five* pounds, *seven* yards, &c. But when the unit does not denote any particular thing, and is expressed simply by *one*, the assemblage formed by collecting together several of such units, is called an abstract number, as *five, seven,* &c. Every kind of concrete number has its particular unit or units, which being known the number itself is known; but it is obvious that all abstract numbers must be measured by the same unit, and are known as soon as named.

To facilitate the management of numbers in arithmetic, they are generally represented by certain arbitrary symbols* which we call figures. Yet it is obviously impossible to have a distinct figure for every number, and accordingly a few only are chosen, and high numbers are represented by combining them according to certain rules. Ten such signs are employed in modern arithmetic, and are given along with their names and meanings in the following table :—

| Figures. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| Names. | cipher | one | two | three | four | five | six | seven | eight | nine |
| Numbers represented | | · | ·· | ··· | ··<br>·· | ···<br>·· | ···<br>··· | ····<br>··· | ····<br>···· | ·····<br>···· |

The method of combining these few symbols, so as to make them represent numbers of every possible magnitude, is both elegant, and simple, though it is usually learned with much difficulty.

5. We perceive that we have nine signs to stand for the first nine numbers, and the cipher to stand for *nothing*, or *zero;* but we have no separate sign for ten. *Ten* is therefore the limit of our separate symbols, and the point where we must begin to combine. It may be asked, why this number was chosen as the limit—why not eight, nine, eleven, or any other? The answer is, that there is no absolute necessity for selecting one number rather than another, as the limit of our simple numbers; but the early arithmeticians of India fixed upon ten, and the Arabians adopted their system, and spread a knowledge of it in Europe, where its superior simplicity was soon acknowledged, and it has accordingly been everywhere adopted. But if we recollect how apt we are, in our first essays in calculation, to count on the fingers, we shall be at no loss to infer the reason why *ten* has thus been fixed upon in preference to all other numbers.

6. Suppose a man has some great number—as the number of revolutions made by the fly-wheel of a steam engine in a given time—to count; and suppose that, in order to help his memory, he holds up a finger for every one he counts, he can thus proceed as far as ten, and then must begin again to reckon the fingers a second time. In this way, by reckoning the fingers again and again, he might count off any number of *tens;* but this is not enough—he must also know the number of times he has had to begin again; that is, the number of tens he has counted. Suppose, then, that he places a person at his left, with instructions to hold up one finger each time he is ready to begin anew; that is, each time that a ten is reckoned. Each finger held up by the first man, will simply denote one; but it is manifest that each finger held up by the second man, acting according to his instructions, will indicate a number equal to all the fingers of the first; that is, ten. Continuing the calculation until all the fingers of the second man are reckoned, and supposing the first man just ready to begin again, then the precise number counted is ten tens, and this is what we express by the term *one hundred.* Now, suppose a third man placed at the left of the second, who holds up a finger whenever he perceives the second ready to begin again; this third man will keep an account of the number of hundreds that are reckoned. One of his fingers will indicate as many as all the ten fingers of the second, and his ten fingers will denote ten hundreds, and for this number we use the term *one thousand.* In this way, each of the fingers of a fourth man would indicate ten thousand; each of those of a fifth, a hundred thousand; and so on. Suppose, further, that the persons engaged are six in number, and that they relinquish their experiment at a time when the first man has seven fingers extended, the second, five; the third, four; the fourth, eight; the fifth, nine; the sixth, three: then, in order to find the whole number of revolutions counted, we might place the results in the following order :—

| 6th | 5th | 4th | 3d | 2d | 1st | |
|---|---|---|---|---|---|---|
| | | | | | 7 | Seven ones, or seven. |
| | | | | 5 | — | Five tens, or fifty. |
| | | | 4 | — | — | Four times ten tens, or four hundred. |
| | | 8 | — | — | — | Eight times ten hundred, or eight thousand. |
| | 9 | — | — | — | — | Nine times ten thousand, or ninety thousand. |
| 3 | — | — | — | — | — | Three times one hundred thousand, or three hundred thousand. |

The whole number reckoned, is therefore *three hundred and ninety-eight thousand, four hundred and fifty-seven.*

7. The next question is, how may such a number be represented in a short and convenient form? This is still a matter of choice. We might denote the tens by marking their number with one accent, the hundreds by two accents, the thousands by three accents, and so on.

$$\text{Thus, } 3''''' \ 9'''' \ 8''' \ 4'' \ 5' \ 7, \text{ or, } 7 \ 5' \ 4'' \ 8''' \ 9'''' \ 3'''''$$

Or we might arrange the figures in any order; because their meaning would depend on the accents which are attached to them, and would have no relation to the place in which they stand.† Adhering, however, to some determinate order, as,

$$3''''' \ 9'''' \ 8''' \ 4'' \ 5' \ 7,$$

it is readily seen that these accents are unnecessary and cumbersome. For, since the figure having the single accent will always stand in the second place from the right, that having the double accent, in the third place from the right, and so on; the *place* which each figure occupies will always point out what accents it should have; that is, whether it denotes ones (units), tens, hundreds, thousands, or any higher order. Thus, observing that the ones (7) occupy the place on the right, that the tens ($5'$) occupy the second place, the hundreds ($4''$) occupy the third place, and so on, each figure is sufficiently well known by the place in which it is; that is, by the number of figures which come upon the right of it. Thus, in 33333, each 3 stands for three of something, according to its place; the 3 on the right hand for three pebbles, (supposing pebbles to have been the things counted;) the 3 in the second place, for three collections of ten pebbles each; the 3 in the third place, for three collections of one hundred each, and so on. From this and similar examples the rule is obvious: *each figure placed on the left of another assumes a value ten times greater than if it occupied the place of the latter.*

8. It may still appear that this rule is not applicable to such numbers as $3''''\ 5''\ 6$, and that accents are still necessary to prevent such a number from being mistaken for $3''\ 5'\ 6$, or the like. But this difficulty is removed by the using of the cipher to bring each figure to its proper place; that is, the place allotted to the sort of collection which it represents. Thus, $3''''\ 5''\ 6$ may evidently be written, $3''''\ 0'''\ 5''\ 0'\ 6$, for 0 means nothing, and has, therefore, in no other way affected the value of the number, than by filling up the singly and trebly accented places which were vacant, there being no odd thousands or odd tens to denote. Leaving out the accents as before, the number is 30,506.

| | | |
|---|---|---|
| Similarly, $1'$ | is represented by | 10 |
| $2''$ | . . . . . . . | 200 |
| $3'''$ | . . . . . . . | 3000 |
| $4''''$ | . . . . . . . | 40000 |
| $5'''''$ | . . . . . . . | 500000 |

and so on, the ciphers serving to denote the order of the significant figures, exactly in the same manner as the accents.

9. When a number requires more than three figures to express it, then it is customary to divide it into periods of *three* figures each, reckoning from right to left, and to distinguish each by a peculiar name, as shown in the following table.‡

* A *symbol* is any sign for a quantity which is not the quantity itself. If a man count his sheep by pebbles, the pebbles would be symbols of the sheep. Our symbols are marks upon paper, of which the meaning of every one is determined as soon as the meaning of 1 is determined. They are, moreover, *arbitrary;* that is, any others would have done. It is 2 that stands for 1 and 1 taken together, and not $<$, $>$, $\vee$ or anything else, because certain Hindoos choose that it should be so.—*De Morgan, Elements of Algebra.*

† The use of accents would also preclude the necessity of the cipher, for 10 would be denoted by $1'$, and 101 would be written $1''1$, &c. The method would be perfectly exact, but not so simple and convenient as that adopted.

‡ The periods might equally be composed of two or four figures each; but in a given number, there would have been more periods in one case, and fewer in

NUMERATION TABLE.

| | | |
|---|---|---|
| I. | Units . . . . . | 1 Units, 2 Tens, 3 Hundreds |
| II. | Thousands . . | 4 Units, 5 Tens, 6 Hundreds |
| III. | Millions . . . | 7 Units, 8 Tens, 9 Hundreds |
| IV. | Billions . . . . | 10 Units, 11 Tens, 12 Hundreds |
| V. | Trillions . . . | 13 Units, 14 Tens, 15 Hundreds |
| VI. | Quadrillions . | 16 Units, 17 Tens, 18 Hundreds &c. |
| | &c. | |

The periods succeeding those contained in the table are *quintillions, sextillions, septillions, octillions, nonillions*, and analogous names might be formed for still higher periods. Those given, however, are more than sufficient to express any number which it is ever necessary to designate in language. Such, indeed, is the facility with which large numbers are expressed, both by figures and language, that we have generally a very imperfect conception of their real magnitudes. For instance, we can pronounce readily the word *billion*, yet calculation informs us that there are not a billion of seconds in seven hundred and sixty-one years. Our eight hundred millions of national debt would, if represented by ten-pound notes of the Bank of England, each only the hundredth part of an inch in thickness, form a pile nearly thirteen miles high. To tell it in sovereigns, at the rate of a hundred every minute, for twelve hours a-day, (Sundays included,) would occupy one man for more than thirty years.

10. There cannot be now much difficulty in enunciating any number already expressed in figures. If we take a number, as 67543, we observe that it is composed of

6 tens of thousands, 7 thousands, 5 hundreds, 4 tens, and 3 units, or 67 thousands 5 hundred and 43,

which is the common form of enunciation.

Again, 17060080, divided into periods, is 17,060,080, and may be read

1 ten million, 7 millions, 6 ten thousands, 8 tens, or shortly, 17 million 60 thousand and 80.

the other, than when they are formed by three figures each. And observing the limits of the numbers most frequently in use, it will be seen that the most convenient periods are those of three figures. It must, however, be noticed, that it is customary in England to reckon by double periods, or periods of six figures each, as in the following table :—

COMMON NUMERATION TABLE.

| | | |
|---|---|---|
| I. | Units . . | 1 Units, 2 Tens, 3 Hundreds, 4 Thousands, 5 Tens of Thousands, 6 Hundreds of Thousands |
| II. | Millions . . | 7 Units, 8 Tens, 9 Hundreds, 10 Thousands, 11 Tens of Thousands, 12 Hundreds of Thousands |
| III. | Billions . | 13 Units, 14 Tens, 15 Hundreds, 16 Thousands, 17 Tens of Thousands, 18 Hundreds of Thousands |
| IV. | Trillions . . | 19 Units, 20 Tens, 21 Hundreds, 22 Thousands, 23 Tens of Thousands, 24 Hundreds of Thousands |
| V | Quadrillions . | 25 Units, 26 Tens, 27 Hundreds, 28 Thousands, 29 Tens of Thousands, 30 Hundreds of Thousands |
| VI. | Quintillions | 31 Units, 32 Tens, 33 Hundreds, 34 Thousands, 35 Tens of Thousands, 36 Hundreds of Thousands, &c. |
| | &c. | |

This is the table usually given in our English works on arithmetic, but it is now beginning to be laid aside for the far more elegant and simple method shown in the table of the text, which is used in all parts of the continent. The methods, moreover, agree as far as hundreds of millions, and it is rarely necessary to name higher numbers.

The following are other examples in illustration :—

| Bills. Mills. Thous. Units. | | |
|---|---|---|
| 708, 000, 906, 000 | is read | Seven hundred and eight billions, nine hundred and six thousand. |
| 78, 906, 000, 400 | | Seventy-eight billions, nine hundred and six millions, four hundred. |
| 7, 800, 600, 040 | | Seven billions, eight hundred millions, six hundred thousand and forty. |
| 789, 060, 004 | | Seven hundred and eighty-nine millions, sixty thousand and four. |
| 78, 906, 000 | | Seventy-eight millions, nine hundred and six thousand. |
| 7, 890, 600 | | Seven millions, eight hundred and ninety thousand, six hundred. |
| 789, 060 | | Seven hundred and eighty-nine thousand and sixty. |
| 78, 906 | | Seventy-eight thousand, nine hundred and six. |
| 7, 890 | | Seven thousand, eight hundred and ninety. |
| 789 | | Seven hundred and eighty-nine. |

The following numbers present no greater difficulty, viz.,

106, 1803, 98769, 80567804, 207000080, 108365, 9007867, 8006783401.

11. The expression of numbers by means of figures presents in reality no greater difficulty; for, each period being enunciated and qualified, it only remains to write each of them separately, and give it the rank which its name indicates. In the first trials, however, it may be advisable to make as many points as the highest name requires, and to mark off these into periods; the significant figures may then be written in their places, under the dots, and the blanks filled with ciphers. Thus, supposing the number to be written down is *five hundred and six million eight thousand and nine*, we know that the place of the *hundreds of millions* is the last of the third period; there must consequently be *nine* figures, or three periods, in the number, and we proceed accordingly to make three periods of dots,

| Millions. | Thousands. | Units. |
|---|---|---|
| . . . | . . . | . . . |
| 5 6 | 8 | 9 |

and filling up the unoccupied places with ciphers, we get for the true expression of the number,

506,008,009.

By a little practice the dots will be found unnecessary, and, of course, need not be used.

The following are examples of the same kind :—

| Name. | Written. |
|---|---|
| Three hundred and nine . . . . . . . . . | 309 |
| Seven thousand and sixty . . . . . . . . | 7,060 |
| Twenty thousand five hundred . . . . . . . | 20,500 |
| Two millions one thousand and eleven . . . | 2,001,011 |
| One hundred and two millions five hundred and seventy-four . . . . . . . . . | 102,000,574 |
| Twenty billions one million forty thousand one hundred and forty-nine . . . . | 20,001,040,149 |

There will now be little difficulty in writing the signs for

Five hundred and eighty-nine,
Three thousand and thirty-seven,
Sixty-four thousand and eleven,
One million two thousand and five,
Four hundred and forty-eight millions.

12. The method of expressing numbers by means of signs, is usually distinguished by the term *notation*, and the method of reading numbers already so expressed, is termed *numeration*. The distinction does not, however, appear to be very necessary, and accordingly we often find writers using one or other of the terms indifferently to designate both the one and the other.

13. The method of numeration which we have here described, is comformable to what is denominated the *decimal system.** But besides this there are other systems in common use. For example, we measure wood, &c., by feet and inches, the foot being equal to 12 inches, and the inch to 12 parts; that is, each

* *Decimal* from the Latin word *decem*, ten; because the value of the figures *increase* in a tenfold proportion from right to left, and consequently *decrease* in the same proportion from left to right.

superior name contains 12 units of its next inferior name; this system is therefore called the *duodecimal system* (from the Latin word for *twelve*). Our mode of counting money is a mixture of systems. We divide it into pounds, shillings, and pence, of which 12 pence make a shilling, and 20 shillings a pound. We write a number of pounds, shillings, and pence, thus, £2 : 5 : 11, where £ shows that 2 is pounds, and as shillings is the next lower name, and pence the next in succession to shillings, the meanings of the 5 and the 11 are obvious. This variation in the value of the units renders the calculation of sums of money more complex than those with abstract numbers. The same is likewise true of all our systems of weights and measures, as we will hereafter find.

14. The systems of arithmetical notation employed by the ancients, were exceedingly inconvenient and imperfect. They served laboriously to register a number that was not very great, but they could not afford the slightest aid in performing arithmetical computation. In the simple calculations which it was absolutely necessary to make, recourse was had to some sort of mechanical contrivance, of which the *Abacus* of the old Romans, and *Swan-pan* of the Chinese, are examples. To form a notion of such an instrument, it is only necessary to suppose a board with a number of lines drawn upon it, as represented in the figure, and that each pebble or counter placed on the space A denotes 1; each on the space B denotes 10; each on the space C denotes 100; and so on; so that, taking the ciphers for counters, the number represented by their disposition in the figure, will be 123142.

| | |
|---|---|
| F | 0 |
| E | 00 |
| D | 000 |
| C | 0 |
| B | 0000 |
| A | 00 |

With such an instrument, (considerably inferior, however,) the Romans made all their heavy calculations,* and noted the results by the letters of their alphabet. This method of writing numbers we have still retained for some purposes, as for marking the chapters of books, the year of the Christian era, hours on dial-plates, and so forth. The letters employed are I, V, X, L, C, D, M; the I to denote 1; the V, 5; the X, 10; the L, 50; the C, 100; the D, 500; and the M, 1000. Iↄ has the same meaning as D, and CIↄ as M. These letters, when thus employed, are called *numerals*, and the principles upon which they are combined, so as to stand for intermediate and for higher numbers, are these:—

The repetition of a letter denotes the repetition of the number it represents; thus, III denotes three ones, and XXX denotes three tens, and so on.

When a letter expressing a less number is placed *after* a greater, the values of the numerals are to be taken together. Thus, XI means ten and one, or eleven; LX means 50 and 10, or 60.

When a numeral of a less value is placed *before* one of greater, its value is to be deducted. Thus, IV means 5 *less* 1, or 4; XL means 50 *less* 10, or 40.

When ↄ is annexed to Iↄ, it increases the value of that character ten times. Thus, Iↄↄ is 5000, and Iↄↄↄ is 50,000. In like manner, CIↄ is increased in value ten times by prefixing C and annexing ↄ. Thus, CCIↄↄ is 10,000, and CCCIↄↄↄ is 100,000.

Lastly, a line drawn *over* a numeral increases its value a thousand times. Thus, $\overline{\mathrm{X}}$ stands for 10,000.

The following table exhibits these principles more fully:—

| Units. | Tens. | Hundreds. | Thousands. |
|---|---|---|---|
| I ............1 | X ..........10 | C ....................100 | M or CIↄ ..............1000 |
| II............2 | XX .......20 | CC....................200 | MM or $\overline{\mathrm{II}}$..............2000 |
| III ..........3 | XXX.....30 | CCC..................300 | MMM or $\overline{\mathrm{III}}$ ..........3000 |
| IIII or IV...4 | XL.......40 | CCCC or CD........400 | MMMM or $\overline{\mathrm{IV}}$........4000 |
| V..............5 | L..........50 | D or Iↄ...............500 | Iↄↄ or $\overline{\mathrm{V}}$...............5000 |
| VI ............6 | LX.......60 | DC or IↄC ..........600 | IↄↄM or $\overline{\mathrm{VI}}$...........6000 |
| VII ..........7 | LXX .....70 | DCC or IↄCC.......700 | IↄↄMM or $\overline{\mathrm{VII}}$ .......7000 |
| VIII..........8 | LXXX...80 | DCCC or IↄCCC...800 | IↄↄMMM or $\overline{\mathrm{VIII}}$...8000 |
| IX............9 | XC .......90 | CM....................900 | IↄↄMMMM or $\overline{\mathrm{IX}}$...9000 |

* The word *calculation* is derived from *calculus*, a pebble, pebbles being originally used on the abacus. In process of luxury, *tali* or little dies made of ivory, were used instead of pebbles, and small silver coins instead of counters.

The following particular cases of combination may be observed:—

| | | |
|---|---|---|
| XVII for...............17 | DCCXIX for.........719 | $\overline{\mathrm{VII}}$CC for ...........7,200 |
| XXIV.................24 | CDXC, or XD........490 | $\overline{\mathrm{XXX}}$XC..........30,090 |
| XXXIX...............39 | MDCCCXLI........1841 | CCIↄↄXL.........10,040 |

## ANATOMY AND PHYSIOLOGY.

### CHAPTER I.

#### INTRODUCTION.

There is *no subject* in which the people are so deeply interested as to know the structure and functions of their own bodies. And yet there is *nothing* of which they are in general so deplorably ignorant. In the pulpit they sometimes hear the exclamation, "that they are fearfully and wonderfully made," but it constitutes the sum and substance of their anatomical knowledge. How astonishing that mankind should exhibit so little curiosity to know themselves! Why do this apathy and ignorance prevail? It is because anatomy and physiology do *not* form an elementary branch of juvenile education. Juvenile teachers do *not* understand them, and therefore *cannot* impart them.

In consonance with the ignorance and practice of the old pedagogues of our ancestors, children are still compelled to waste too much of the best portion of their early lives in the useless study of guttural sounds, obsolete words, dead languages, Greek and Latin poetry, ecclesiastical dogmas, and abstruse catechisms; and this is boastingly misnamed a useful education. What a misnomer of knowledge! It is like gravely presenting an apprentice-boy a few childish toys to play with, instead of giving him useful tools and teaching him his trade. It is like teaching astrology instead of astronomy—alchemy instead of chemistry—metaphysics instead of phrenology—magic instead of science—charlatanerie instead of surgery—and superstition instead of wisdom. It is making mankind move forever in one limited circle, and beyond it everything seems dark and mysterious. It is teaching them to quake like children at a thunder-storm, instead of disclosing the laws of electric phenomena—pointing the iron rod to the clouds, and directing the lightning to pass harmlessly into the earth. It is glorious for mankind that some philosophers have boldly overleapt the prescribed limits of their scholastic education, fearlessly examined the structure and laws of matter, and honestly explained them to the people. Galileo, Franklin, and Sir Isaac Newton, have burst the gates of superstition, opened to us the lucid windows of heaven, and we now behold the celestial phenomena with rational delight, and understand them.

Harvey discovered the circulation of the blood only by examining the human body, and studying its laws—not by bowing down with reverence to the dogmas of schools—and he banished from anatomical cloisters the hypothetic jargon of licensed empiricism, and in despite of medical anathemas and persecution, gloriously triumphed. Jenner unfolded the safety and utility of *vaccine inoculation*, and preserved the lives of millions of human beings, notwithstanding the outrages and selfishness of all the medical faculties of Europe combined to destroy it. Hundreds of anatomists, in almost every kingdom, have secretly dissected dead bodies, and disclosed their structure and functions to their pupils, although the arm of popular violence was often raised to annihilate them. In our own land, Sir Charles Bell has reaped immortal fame by his anatomical researches, and has explained the mechanism and laws of the animal machine to chirurgeons with as much accuracy and simplicity, as Watt has unfolded to engineers his extraordinary, yet simple, hydraulic engine.

In one short essay, very little knowledge can be conveyed of the structure and functions of the human body; it is only by commencing at the beginning of the subject, and proceeding with a regular series of articles in succeeding monthly journals to its termination, that we can learn to comprehend ourselves; and, after minute investigation, the skilful arrangement, symmetry, uses, and beauty of the animal machine will be rationally per-

ceived and appreciated. We admire the steam-engine—it is worthy of admiration—it is one of the greatest and most useful inventions of *man;* but *man* is a machine, that for mechanical arrangement and accurate adaptation, as far surpasses *it*, as a natural plant excels an artificial flower. There is nothing like *man* in organic matter. He bears *upon him*, and *within him*, the impression of his almighty Creator. No man can be an atheist who understands the structure and laws of his own body. From conception till death, we are endowed with a mysterious vitality; and when our mortal destiny is finished, life extinguishes, and our bodies resolve into the elements that compose them. This is an organic law of nature, inexplicable, immutable, irrevocable; and no animal is exempted from its fatality.

The human body is composed of parts; *each part* constitutes a *separate* economy, depending on the *whole*, and the *whole* is sustained by its *parts.* Internally there is a strong *framework* of bones, and on *these* the superstructure is built: over the bones is laid a thick bed of muscular flesh, in regular thin layers, composed of long slender fibres, each layer acting like a pulley, raising and depressing the bones at the will of the individual. To the extremity of each of the deep-seated muscles (over the bones,) a piece of strong white tendinous cord is attached, and inserted into the bone, by which it is moved and motion is performed; the joints are mechanically constructed, and nicely adapted to each other, and attached by ligamentous bands that bind them together and prevent dislocation. In the bones, in the muscular flesh, and in every part of the body, blood-vessels, composed of arteries and veins, ramify in every direction, from the thickness of a child's wrist, to an almost imperceptible thread. The arteries convey the oxygenized blood to every part of the body, to repair its waste, and cause it to grow. The veins return the carbonized blood back to the heart, unfit for nutrition, to be re-oxygenized by the inhalation of atmospheric air in the lungs, and deprived (by expiration,) of the carbon and hydrogen that rendered it destructive to animal life.

In the abdomen (or belly,) we have the stomach, bowels, liver, spleen, pancreas, and kidneys, each and all performing their separate work, with silence, order, and harmony. The stomach receives the masticated food, and, by its gastric juice, digests it. It requires about four hours to complete healthy digestion. The liver pours its bile into the duodenum (or first gut), assists digestion, separates the nutritious from the excrementitious aliment, and aids the expulsion of the latter. In the upper region of the bowels, the lacteals (little absorbent vessels,) suck the nourishing part of the food, and send it, by the mesenteric glands, into the receptacle of the chyle; it then passes into the chyle-duct, (transformed into a milky fluid,) and ascends, by muscular action, contrary to the laws of gravity, until beneath the left-shoulder it oozes into the left sub-clavian vein, and mingles with the blood.

In the chest we have the lungs, composed of delicate cells and blood-vessels, receiving and expelling the respired air. The circulating fluid passes from the heart into the lungs, and is there exposed to the action of the air we breathe. It parts with the carbonic acid, hydrogen, and watery vapour which it imbibed in circulation, and absorbs oxygen; changes from a dark-purple to a bright scarlet-red, returns to the heart, and is sent, by the simultaneous action of the arteries, into every part of the body, to nourish and repair it. This extraordinary process never ceases till we die. In every age and clime it proceeds with the same regularity, without our consciousness and will. There are about twenty-five pounds of blood in a full-grown man.

In the hollow of the skull we have the brain—the most mysterious organ in nature. It is divided into two hemispheres, several lobes, and enclosed in three membranes. We have two distinct brains—the cerebrum before, and the cerebellum behind: the spinal cord is a prolongation of the brain, enclosed in twenty-four bones, joined together by intermediate cartilages, that render it flexible, and by the nicest mechanism, prevents spinal compression. From the brain and spinal cord numerous nerves extend in every direction, from the thickness of the little finger, to the finest gossamer-thread; giving life, sensation, and motion, to every part of the body. The brain seems to be an animo-galvanic apparatus, in which the vital principle is generated, and the nerves are vital conductors. The nerves of the senses communicate between the mind and the external world through the medium of the brain. The spinal cord derives its function directly from the brain, and gives motion and sensation (by two sets of nerves) to the parts supplied. The heart and arteries pulsate by nervous power, received from the brain, and are stimulated by the circulating blood. We move our bodies by nervous energy derived from the spinal cord and the brain. We see, hear, taste, feel, smell, eat, drink, digest, grow, and renew, by nervous influence, that has its *origin* in the brain. The mind resides in the brain; we cannot live, think, reason, judge, nor do any thing vital and rational, without the brain; it is the material organ of the mind, by which she communicates with the external world, and without *it* she is a *nonentity.* It is her sanctum-sanctorum, where she resides in mysterious silence, and cogitates on nature and revelation, bounds in thought through universal space, roams from time to eternity, and bows with adoration at the footstool of the Eternal.

To make the animal machine a little world, individualized and perfect, the external *skin* completely envelops and preserves it in complicated unity, and is beautifully finished by the almighty hand of our infinite Creator.

The animal machine is self-preserving and self-propagating. The blood circulating in the body is deposited in minute quantities, (wherever it is required,) and supplies the bodily waste and repairs its injuries; and all the parts of the body are composed of blood. As we begin to grow old, the organs that form the blood become diseased, deteriorate its quantity and quality, and render it unfit for animal nourishment; hence the progress of decay, with advancing age. By the union of the sexes, the human race is propagated by a process, mysterious, natural and unknown.

Notwithstanding the perfection and beauty of the animal machine, there exists in its constitution a mysterious necessity for death. When *man* passes the meridian of life, he is gradually dying, and before *threescore and ten years* pass over him, his appearance indicates the progress of approaching dissolution. His hair becomes white—his brow bald—his face wrinkled—his hands shrivelled, and his feet cold. His eyes grow dim—hearing is dull—smelling imperfect—taste impaired, and the sense of touch blunted. His limbs move slowly and tottering, and he leans for support on his staff. His heart beats slow and intermits—the blood circulates sluggishly—he breathes heavy and oppressed—his bowels are inactive, and the appetite is sick. Dull, wearisome, sleepless nights creep over him, and morning returns without administering comfort to his torpid brain. He is querulous, irritable, and childish, and feels little delight in events that glide on before him. His *mind* broods on the past, and the recollection of his early years and departed friends haunt his torpid brain; at night on his couch, he dreams of the dead, and at noon, talks of the dead in his lonely walks. He exists the mere wreck of what he was; the summer sun sickens him, the winter wind chills him, and the eastern blasts make him shiver. His grand-children, and great-grand-children gather around him, and climb his knees—he loves them, and tells them tales of departed years. He is the *last sad relic* of his father's house—the *lonely existing unit* that joins the *present* to the *past.* His *mind*, still pleased with her existence, sits unconcerned amid the ruin, sheds a feeble glimmer over her frail tenement, and fondly clings to its desolation. On a cold February night, the east-wind howls and inflames his lungs—he complains of a dull pain in his chest—is restless, thirsty, and feverish, picks the wool from his bed-clothes, raves of his *parents* and departed *wife*, mutters incoherent ejaculations, and *dies.*

"No sooner has he breathed his last, than those chemical agents, external and constitutional, which, when subservient to life, kept him from decomposing, now usurp the supremacy, and begin to decompose that fabric, which formerly they not only had reared, but likewise preserved; ammoniacal and inflammable gases evolve before the body be buried." If the grave is warm and dry, the body rapidly decomposes. If cold and moist, it for a long time resists putrefaction; *years pass away*—the body is fast decomposing, and shall soon return to the elements that formed it; *ages pass away*—the soft parts are decomposed, and a few crumbling bones are all that remain; *centuries pass away*—the mouldering bones have also disappeared, and nothing can be discovered and collected, of the *mysterious fabric*, that once lived, and grew, and propagated, and died. Search the grave for the wreck of *man*, who existed a thousand years ago, it is not to be found among the memorials of mortality. It has been reduced into its simple elements, and has become, in irregular succession, part of other animals, minerals, water, earth, air, and plants. The same elements that compose our

*bodies may have already passed, and may yet pass through every variety of combination in nature.*

Shall the *dead rise* from the grave, is an awful and mysterious subject? I will briefly dismiss it in a few words. Our almighty Creator has *promised* in his *word*, and is *able* to *raise us again* from the *dead.*

The chemical analysis of the human body teaches us that the *rich* and *poor man*, and the *lower animals*, are composed of the *same simple elements*; a *few gases* in varied combination, constitute the greater portion of the animal frame. Is it o these *gases*, that *man* is so *vain* and *proud?* Is it only to increase their *volume* that he explores every *portion* of the globe for luxuries to sate his voluptuous appetite, to add a few more *atoms* to his flesh, and a few *pounds* of *lime* to his *bones?* Let the pampered lordling who is proud of his *status*, be told, that 63 parts in the 100 of his *bones*, are composed of *lime* in combination with *acids*, and we may make him humble. Let female beauty be told that the *red* part of the blood which flushes her cheeks, is composed of *iron*, in combination with *oxygen*, and we may cure self-idolatry. Let the vain man of *genius* be told that his large, lofty, prominent brain, is chiefly composed of soda, lime, and ammonia, combined with phosphorus, oxygen, and a small portion of sulphur, and we may humble his intellectual vanity. Yet these statements are true; for they are founded on chemical analysis, that cannot err, and are as immutable and correct as mathematics. The human *mind* is immaterial and invisible, and cannot be analyzed by chemical laws,—its *composition* shall therefore remain for ever *unknown to the peasant and philosopher.*

In next chapter we will describe the skin and perspiration.

## GEOLOGY.

### CHAPTER I.

INTRODUCTION.—ORIGINAL CONDITION OF THE EARTH AND ITS ANTIQUITY.

Railway excursions are no way adapted for geological observation, and but little can be learned from the deck of a steamboat. If you wish to understand the structure of the earth, you must take your hammer in your hand, and peregrinate through the breadth and length of the land; ascend the hill, dive into the ravine, descend the mine, explore the river, and investigate the shore. Unless you can undergo this fatigue for the sake of truth, and the acquirement of knowledge, Geology will never completely open up her treasures to your understanding: read, and speculate, and wonder you may, but unless you are a working, you can never be a practical Geologist. But though all are not capable of undertaking this laborious task, and still fewer have time, truth is not to be hid from their understandings, and the general deductions of geological investigation may be made known. This science of late years has engaged no small share of public attention; and why so? because, more than any other science, it effects a revolution in our mode of thinking, concerning the origin of the earth and the progress of nature—discloses the secrets of a vast antiquity—unfolds the outgoings of the *Ancient of Days*, and the successive operations of his hand, even when the foundations of the earth were being laid, and through a long succession of epochs of indefinite duration.

Accustomed to consider the whole of nature as having sprung out of nothing at the Divine command in the course of a few days—and erroneously deeming this belief as essentially connected with the fundamental articles of Christian faith—it is little wonder when Hutton announced to the world that the earth afforded no trace of a commencement, nor any prospect of an end, that he was assailed as an infidel. But time effects changes in the moral as well as the physical world, and such a belief is now considered no way obnoxious to a true interpretation of the sacred text: some of our divines are amongst our most celebrated geologists, and the vast antiquity of the earth has become as fully accredited by churchmen as if it had formed a subject of distinct revelation. A few cavillers are still to be found, but not amongst the enlightened and the liberal portion of the Christian community; it is only among those who, assuming their preconceptions to be true, and their interpretations of scripture right, peril the credibility of their faith before the stubborn evidence of fact. The vast antiquity of our globe is now as fully demonstrated as its rotundity; and the lapse of ages which must have occurred in the completion of a geological epoch, as evident as the distances of the heavenly spheres: indeed more so—because the one can be proven to any person in the slightest degree conversant with the structure of the earth, by deductions the most rational and satisfactory, and by evidences the most complete; whereas in Astronomy the person who cannot apply the telescopic tube, has in a great measure to rest satisfied with the testimony of the astronomer, and the collateral evidence of the mathematician.

That the stratified portions of our earth have resulted from sedementary depositions, such as those we witness in rivers, at the mouth of estuaries, and in lakes, is evident from the vast abundance, and the perfect state in which their embedded organic remains are found. From the coral to the elephant—from the sea-weed to the lofty pine—the various species of animals and plants, attest the ancient conditions of animal and vegetable life upon the surface of the earth, during each successive period of deposition.

Coralines are found in every period, but each great division differs in the character of the species. Fishes of very different forms from those that now inhabit the ocean, with one or two exceptions, and of a predatory saurian character, prevailed in the ancient deep, and latterly crocodileans crawled upon the shores. The seas teemed with cephalopeds allied to the cuttle fishes and nautilli of the present seas; and wherever there was land a tropical vegetation arose. Seven distinct geological epochs —each characterized by sedimentary deposits of enormous thickness, and each the work of many thousands if not millions of years, and by the existence of distinct species of animals and plants—occurred previous to the introduction of an order of Nature analogous to the present; when mammiferous animals constitute the chief occupants of the land, and plants producing timber, and fruit, and flower, are everywhere to be found. Such plants were not required while land animals were few, and these principally confined to the lizard and crocodile tribes, and, therefore, they were not called into existence. *Nothing is made in vain.* But after the introduction of suck-giving animals, such as deer, cows, horses, elephants, and tapirs, which took place only after the chalk rocks had been deposited, we find the elm, the oak, and other exogenous plants to have existed, and Nature to have made a slow, but a gradual approximation to the state in which it seemed fit to Deity to call man into being.

Such is a brief outline of the views of modern geologists with respect to the age of the earth. Unfolding as they do the most evident traces of the continued exercise of creative power, in the production of creatures from time to time fitted to the existing physical conditions of the globe; they offer a most incontrovertible testimony to the existence of an infinitely intelligent and all-powerful First Cause, and thus lay the foundation of a true knowledge of the Great Architect of the universe.

That the earth is round, performs a revolution on its axis daily, and moves with inconceivable velocity in the path of its orbit round the sun once a-year, are facts now familiar to every school-boy. It is also well known that the earth is not of a perfectly round, but of a spheroidal form, its polar axis being about twenty-six miles less than its equatorial diameter. The spheroidal figure of the earth is common to that of the planetary bodies. It is that which bodies necessarily assume whose particles have free motion among themselves, when subject to a rotatory motion like the earth; hence it is inferred that the whole matter of the globe once existed in a fluid state—a supposition strongly confirmed by its other phenomena. What form the first consolidated masses assumed, whether any such now exist, we have scarcely sufficient data given us to judge; but the oldest stratified rocks, Gneiss and Mica Slate, being evidently derived from the disintegration of Granite, it is not improbable that the original mass, when first consolidated, assumed the different crystalline forms of that rock. Lyell, it is true, has carried his metamorphic theory so far as to consider Granite itself to have resulted from rocks of a prior origin, and that the tendency of all rocks, however new, is to pass onward to the metamorphic state evinced by Granite and the

rocks usually denominated primary; we are, however, disposed to agree rather with Phillips, and consider Gneiss and Mica Slate as depositions of matter derived from the granitic floor of the earth, and that granite represents the primordial condition of the *crust* of the globe. Its state of crystallization shows its former fluidity, for fluidity is indispensable to the process of crystallization; and hence, from the nature of granite, as well as the figure of the earth, we are warranted to believe in its original fluidity. The only cause of that fluidity could be heat, and the radiation of that heat the cause of its ultimate solidity.

The mean density of the earth has been estimated at five times that of water, or twice that of the known solid substances, taken together, which constitute the crust.

It becomes then a question, in what state the interior masses are?—are they solid, fluid, or aeriform? In whatever state they exist, it must be evident they are much more dense than the exterior masses. This superior density may arise either from the substances being naturally heavier, under equal conditions, or it may result from the greater compression to which they are subjected from the superincumbent masses. Sir John Leslie computed that air, under the law of uniform condensation, would become as dense as water at the depth of $33\frac{3}{4}$ miles; and at a further depth it would acquire the weight of quicksilver: water, at the depth of 93 miles, would be compressed to half its former bulk, and at $362\frac{1}{2}$ miles would be as dense as quicksilver; and that air, from its greater compressibility, would acquire the same density as water, sooner than water would reach the condensation of marble. From these facts he concludes, that our planet must have a wide cavernous structure, and that we tread on a crust or shell, whose thickness bears but a small proportion to the diameter of its sphere. "An absolute void being inadmissible, the vast subterranean cavity must be filled with some very diffusive medium of astonishing elasticity or internal repulsion among its molecules. The only fluid we know possessing that character is *light* itself, which, when imbodied, constitutes elemental heat or fire." "This spacious internal vault," he concludes, "must contain the purest etherial essence, LIGHT, in its most concentrated state, shining with intense refulgence, and overpowering splendour!!!" We offer no opinion as to the plausibility of this very brilliant speculation; we only adduce it as an instance to what fancy may lead, when the actual condition of the substances speculated upon is entirely removed from observation.

That the central parts of the earth, however, are warmer than its exterior crust, is proven by numberless experiments made in deep mines, coal-pits, and from the waters of Artesian wells. The result of these experiments has been to show, that the earth increases in temperature at the rate of 1° Fah. for about every 50 feet of descent from the surface, increasing in a greater ratio in descent. Should this heat continue to increase in the same ratio, on descent beyond ascertained depths, it is evident that the central parts of the earth must be intensely hot—a supposition that well accords with the existence of active and extinct volcanos and thermal springs, the production of those vast masses of molten matter which in every age has been poured out from subterranean sources; and above all, with the altered condition of the metamorphic and primary strata.

The admission of central heat, of and the ancient fluidity of all terrestrial matter, involves important considerations as to the remoteness of the period of original consolidation. Bodies radiate their heat according to a fixed law, viz., a body loses one-half less heat in any given period than in that which preceded it; that is to say, if the earth lost one degree of heat in a hundred years, in the following hundred years it would only lose one-half of a degree. Laplace applied his great powers to the calculation of the time required for the refrigeration of the earth in any given time; and found that many hundreds of millions of centuries must have elapsed since the crust of the earth could be materially different in temperature from what it now is—its decrease of temperature at present not being more than one-twentieth of a degree in a million of centuries!!!

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# HISTORY

## INTRODUCTION.

HOW HISTORY OUGHT TO BE STUDIED—THE NATURE OF HISTORICAL EVIDENCE—THE ADVANTAGES OF STUDYING HISTORY—OUTLINE OF THE HISTORY OF EUROPEAN CIVILIZATION.

"STUDY history" is an advice frequently given to young men: it is sound advice, but, unfortunately, rarely understood either by the giver or receiver.

To study history, something more is necessary than to read with interest and attention, and with a retentive memory, any number of books called histories. To store the mind with facts is only one of the useful ends to be obtained by the study of history; and even that cannot be attained by merely committing to memory the statements of that class of writers called historians. These statements are not necessarily facts. They are merely the opinions entertained by the writers of history as to what are facts. They are evidence of facts—evidence sometimes of more and sometimes of less validity, but evidence which, in not one instance, is entitled to implicit and uninquiring acceptance.

To illustrate this. All histories may be divided into two great classes, which admit of subdivisions, giving us the following four classes of histories:—

1. Histories compiled by individuals who lived posterior to the times in which the events they narrate occurred; such histories being compiled from records more or less fragmentary.
2. Histories compiled from hearsay, by persons who lived at the time the events narrated occurred.
3. Histories compiled by contemporaries who were mere spectators of the evils they narrate.
4. Histories compiled by individuals who took an active part in the event they narrate.

The value of the testimony borne by each of these classes to the facts narrated in them, is widely different. The testimony of the third and fourth classes is the direct evidence of eye-witnesses; the testimony of the first and second is only second-hand, or hearsay evidence. Again, the value of the testimony of a contemporary, who was a mere spectator, differs from the value of the testimony of a contemporary who was an actor in the events narrated. The mere spectator is ignorant of secret intentions and motives, and sees only the fair outside exposed to the eyes of the world: hence his opinions of the purposes of action, and his calculations of the adequacy of exertions to the ends in view, and his estimates of their success are subject to frequent and great errors. Actors in the scenes narrated, on the other hand, know the real springs of action; but then their knowledge is often partial, and confined to the motives and intentions of their coadjutors;—of those of their opponents they are necessarily in ignorance, and are often led to distort their projects and wishes. The knowledge of the mere spectator is more general than that of the actor, and, in most cases, more impartial, but on many points more vague and superficial. That of the actor, on the other hand, is more minute, complete, and accurate in part, but less extensive, and more apt to be tinged by prejudice. In like manner, the testimony of the first and second classes, both of them hearsay evidence, differs materially. The contemporary compiler from the oral or written narrative of others has the advantage of him who lives in a later age, that treating of the actions of those living, in a great measure, under similar circumstances to himself, many things are clear to him which must be unintelligible to the latter. On the other hand, the writer of a later age has, not unfrequently, at his command a richer collection of materials. Many secrets have transpired, carefully guarded during the lives of those who might have been affected by their revelation, which cast an entirely new light upon events. Those incidents, moreover, which appear to the contemporary unmeaning and anomalous, are seen by him who comes after, duly linked into the great chain of events. He, too, who sits in judgment on the actions of the dead, is less apt to be biassed by transient passions, than he who, living at the time of these actions, may, however distant from, and unconnected with, the actors, have a common interest with them. The

present object of this analysis is not to furnish materials for constructing a scale whereby to estimate the relativo trust-worthiness of these different classes of authors : it is merely to establish the position, that all of them have their weak sides—that the statements of none of them can be received implicitly.

There is another reason why historical works are, of themselves alone, insufficient to teach us adequately what they profess to teach. Contemporary historians are entitled to assume a knowledge of many matters in readers of their own age, of which readers of a subsequent age are necessarily ignorant ; a knowledgo of which, however, is necessary for the right understanding of their narrative. No man, while writing the events of his own time, can know by anticipation what usages, laws, or social relations are to become obsolete, or the mode of their transmutation. Historians who live subsequently to the time of the events they narrate, are as ignorant as their readers of these matters. They are obliged to eke out the fragmentary contemporary narrative from which they compilo their story. But much of this patch-work is guess or inference, made more or less felicitously upon data more or less full or trust-worthy. It is in too few, not a statoment of fact, but of mere opinion. We cannot rely upon it as evidence, unless we examine for ourselves the ground-work upon which it rests. Again, every historian, almost, has an object in view beyond the mere recording of facts. Even Herodotus, the father of history, made his history subservient to the purpose of elucidating the animosity which in his day existed between the great antagonist powers of Greece and Persia. Hume compiled his history with a view to convince men that the Stuart dynasty was not so utterly bad as men had been in the habit of believing. Brodie compiled his to show that Hume had mistaken or misrepresented the nature of the British constitution at the commencement of the seventeenth century. This subordination of narrative to the purpose of making men adopt the author's private opinions of events; this indirect special pleading, in fact, not only exposes the writer to the charge of being biassed in receiving and representing facts, but it leads him to pass over in silence much that is necessary to a right understanding of events, and of the motives and circumstances of the actors and sufferers in them.

Other sources of information, therefore, are necessary to enable us to apply some external standard to aid us in estimating the comparative trust-worthiness of conflicting statements, or to piece out the fragmentary narratives conveyed even by the last historians. The nature of these sources will be best pointed out by an example. Take for this purpose a portion of the history of Greece.

A consecutive history of an interesting period of the ancient Grecian states will be found in the works of Herodotus and Thucydides, and in the work of Xenophon called his Hellenics. Any person, however, who rises from the most careful and critical perusal of these works, will find much that is dark and painfully incomplete in the notions they furnish of the feelings, circumstances, and valuo of the people whose annals he has been studying.

We possess, however, other relics of these days. We have the writings of poets, lyrical, dramatical, and epic, who lived and composed at that period ; or whose writings, handed down from a yet more distant age, were the delight of the men who then lived. We have the writings of philosophers who lived during that era, or in a generation animated by the same emotions, governed by the same laws, and influenced by the same opinions. We have fragments of their laws, and fragmentary notices of their institutions. We have rich and copious specimens of that oratory which exercised such an influence on their affairs, casting a flood of light on their public and domestic arrangements. We have special narratives of military expeditions, and treatises on the art of war. We have majestic remains of their religious structures and places of public resort. We have specimens of their productions in the plastic art. We have inscriptions, some valuable merely as teaching us a custom of the men of these times—some as confirming or correcting a statement of the historians.

Taking all these various sources of information together, we are now able to frame for ourselves a more complete and extensive history of that distant time, than any that has been left to us. To illustrate this, the method of procedure may be thus briefly shown. Taking as a groundwork the three historians just named, we fix the field of inquiry by taking the first positively ascertained year of their annals for the commencement, and their last for the termination. We master, by diligent and critical study, the facts which seem most worthy to be relied on, and arrange them according to their chronological sequence. We then take the fragments of laws, and the fragmentary notices of institutions, and the special narratives of military expeditions and treatises on military affairs. We ascertain, as well as we can, the period to which each belongs, and compare the information we derive from the historian regarding it, and by this means enable ourselves to test the accuracy of his statements, and to fill up, as it were, the outline of knowledge he has traced for us. Next, we proceed to the writings of philosophers ; and, having ascertained the period to which they belong, from them we gather information regarding man and his works—the manner in which men at that time talked of religion and government—and thence derive an insight into the projects of the great men at the head of affairs. We also glean incidental notices of institutions, serving to enlarge our scanty historical knowledge. Some of the writings now alluded to discuss the conduct and duties of man, and from these we obtain glimpses of the pursuits and domestic condition of the private citizen. We are thus furnished with materials for at least guessing the amount and kind of social enjoyment attainable under the protection of the institutions with which our other sources of information had made us acquainted. Our knowledge on this last topic is rendered more complete by those orations relating to private right, discussed in the courts of justice. In like manner the orations treating of public or political affairs, furnish us with a more living conception of the working of the great state machine. It is not with mere facts that these writings furnish us. Their half poetical structure, and the impassioned oratory of the declaimers, awake our emotions, at the same time they store our minds, and teach us to know the men of these old times, as they lived and acted at home and in the forum, and teach us to feel as they felt. The dry bones are stirred, and life again infused into them by our own miracle-working imaginations.

The transition from these sources of knowledge to the poets is easy. In their light and furtive but incessant illusions to passing events, we possess a more dim and shadowy indication of facts ; but we have a warmer and more enduring memorial of the life, of the emotions, and imaginations, of the people to whom they were addressed. In the pages of Æschylus, we learn to tremble beneath the dark phantom of superstition, which hovered over the old inmates of the sunny climes of Greece. In Sophocles we hear the eternal flutterings and liquid notes of his nightingales among his groves of undying laurel ; and the gentle enduring beautiful love of his Antigone, watching over her old blind father, warms and will warm the hearts of men, till time shall be no more. Or turning to that chartered libertine, Aristophanes, we find that his hearty laugh has ensured immortality to what were in their day regarded as common-place trifles; but to us, wishing to know how man existed and busied himself, they are beyond price. Turn we, last of all, to the unsurpassed remains of architectural and sculptural genius, which survive to attest that there were mental giants on the earth in those days. They repeat, with a voice that cannot deceive, the tale of delicate sense, of beauty, of soaring imagination, of superiority to mere vulgar sensual pleasure, so inadequately conveyed by the mere written or printed page.

History, studied in this manner, becomes more than a mere chronological table. It impresses upon the mind more than a mere superficial outline of events, which have taken place on the stage of human existence. The mind so directed is not only cognizant of the rise and fall of great men or of nations, but it comprehends the various phases under which the human race existed in older times ; it can enter into the feelings of antiquity, and have reflected within itself the condition of the people as affected by institutions, by their religion, their superstitions, their habits, their customs, and be able to form a proper estimate of the literary and scientific genius of antiquity. By a visit, or by the aid of the painter, we know how Hymettus rises in air, and how the waters which laved the Salamis, where the hordes of a tyrant were baffled, still circle and mirror the olive groves of Attica. And by the aid of sculptured and architectural fragments, we can rebuild the city of Pericles. We can catch, as the distant mariners did, even from Cape Sunium, the flash of the golden spear-point of the Athena of the Acropolis. We can stand beneath the shadow of the Parthenon, and see the

god-like figures which Phidias taught to look eternal and omnipotent beauty in stone. We can hear in fancy the rhythmic music of Euripides or Aristophanes, rising from the crowded theatre beneath the rock. We can listen to the glad shout of the thronged street, reverberating from Hymettus to Parma, as the embroidered veil of Minerva advances like a banner on the rolling car. We can hear the thunder of Domosthenes, while the solid mass of humanity in the Pnyx stood hushed as death. Or we can sit over the wine-cup with Socrates. Or we can share in the feverish political intrigues of Alcibiades, or own the blandishments of an Aspasia.

This is the rich reward of such a study of history as here described. Nor is it merely as an acquirement, and by its influence upon our thoughts and feelings, and through them upon our character, that this knowledge is important to us. The efforts by which it is acquired are salutary to the mind in the highest degree. The practical exercise of a critical and repeated application of the rules of evidence, the habit of classification and arrangement, of selection and combination—the cultivation of the powers of apprehension and memory, are eminently calculated to awaken and strengthen the intellect. They are an excellent preparatory exercise for drier studies, and for the avocations of busy life. It is not only he whose professional duties call upon him to study the heart of man, and to exercise himself in oral or written communications of his ideas, that is benefited by such a course of study. There is no man in any sphere of life but will find his principles liberalized and invigorated, and his temper rendered more invariable, buoyant, and cheerful by it. Above all, he who has after this patient and exhaustive fashion studied the history of any one period or country, is furnished with an unfailing, innocent, and improving source of amusement for his idle and languid hours. The poets whose perusal has augmented and vivified his historical knowledge, will be brightened up by the reflection of their own light upon themselves. The page of the moralist will suggest to the fancy innumerable trains of self-supplied illustration, to follow out which in reverie is the most delicious and profitable relaxation of the over-tasked man's rare quarter-hour of breathing time. Above all, he who has once, by devoting a portion of his time to mastering in the way indicated, a portion of history, however brief or unimportant in itself, has obtained the mastery of a method which he can apply at any leisure interval with greater facility and with like success to any other portion.

From what has been advanced, it may be asked, is it not possible to compile something like a system of general rules, applicable to the study of all, or any portion or period of history? Such a system may certainly be established; and in this series of articles the attempt will be made, in the first instance, to trace such a code of rules, which may be called the principles of historical inquiry, for the guidance of those who may feel inclined to adventure upon a systematic study of history; and, in the second place, to elucidate these principles, and facilitate their application, by setting the example of treating a definite portion of history in conformity to them.

The portion of history which will be taken up, forming the second part of the series of articles, is, in general terms, the history of European civilization. It commences with the earliest records of the Roman republic, and will be brought down to the present condition of European and American society, and European colonies in different portions of the world. The articles will be arranged in the following order:—

Chapter I.—The history of the Roman republic, from the earliest recorded times till the assumption of supreme power by Julius Cæsar, delineating the condition of the people; the mutual relation of the various classes of society; their advancement in laws, science, morals, and religion.

Chapter II.—Will be an intercalary chapter, to explain matters necessary for the right understanding of Roman history. These are the early history of the territories in Europe, Asia, and Africa, over which Rome held dominion at the close of the republic; as also the early history of the old Italian domains. These foreign dominions, previous to their acquisition by Rome, were governed alternately by one of the great antagonist powers, Persia and Greece; it will therefore be necessary to direct attention to the history of these two empires. The Egyptians and tho Jews, from their retention of a national character, both under the Persian and the Grecian sway, exercised a considerable influence; their history will therefore be noticed.

Chapter III.—This chapter will contain the history of the Roman empire, extending from the usurpation of Julius Cæsar to the extinction of the Western Empire. Attention will not be directed so much to the fortunes of individuals, as to the framework and condition of civil society.

Chapter IV.—This will be another intercalary chapter, sketching the external history of the church—only with reference to its human organization, worldly features, and influence upon society—embracing first the universal church, and subsequently the western church, till the extinction of the Western Empire.

Chapter V.—This chapter will be directed to the efforts of Charlemagne to re-construct a Western Empire. It will consist of three sections:—First, the disorganized state of European society after the extinction of the Western Empire. Second, the legislative efforts of Charlemagne in church and state, and the amount of their success. Third, the fall of the whole of his civil structure, shortly after his death, and the permanence and exclusion of the power of the western church, on the new basis on which he had placed it.

Chapter VI.—Will treat of the history of Europe, from the death of Charlemagne, till the commencement of the ecclesiastical reformation under Luther, considering, in its various bearings, what is commonly called the feudal system; as also the gradual revival of letters, and the rise of a mercantile community.

Chapter VII.—This chapter will extend from the commencement of Luther's mission, till the commencement of the French Revolution. It will be subdivided into three epochs. The first, a rapid *résumé* of preceding events, bearing upon the present period. The second, relating to Luther, and the progress of the religious reformation, properly so called. The third, relating the political discussions, for which the minds of men had been prepared by the religious struggles. This last will embrace the assertion of the independence of Holland—the wars of the League in France—the thirty years' war in Germany—the war of succession—the establishment of Prussia.

Chapter VIII.—This chapter will treat of the history of Europe, from the commencement of the French Revolution. It may be called the constitutional era; as, during this time, the civil constitutions of the European states were undergoing continual change. The spirit of free inquiry in political matters, which had fairly broke loose, was engrossed in theorising on government. The French, or, it may be called, a European Revolution took place, Holland and America established their independence.

Chapter IX.—This will conclude the series, with general reflections upon the past history and present condition of the nations of Europe.

## BIOGRAPHY.

### FRANCIS BACON.

In commencing a series of biographical notices of men who have distinguished themselves in the various branches of human knowledge, we cannot do better than begin with the statesman and philosopher, the father of modern science, Francis Bacon. He was the youngest son of Sir Nicholas Bacon, and was born at York House, in the Strand, London, on the 22d of January, 1561. When a boy, he seems to have been about the court, and received some notice from Queen Elizabeth, for his ingeniousness and intelligence. At the age of thirteen he was sent to Trinity college, where he studied with diligence and success. At the age of sixteen, according to Dr Hawley, his chaplain and biographer, he formed a dislike to the philosophy of Aristotle; not from anything worthless of the author, but because he thought it "a philosophy only strong for disputations and contentions, but barren of the production of works for the life of man."

On leaving Cambridge he entered Gray's Inn as a student of law, where he was made an ancient on the 21st of November, 1576; and, as his attendance was not required in London for

some years, he went to France in the suite of Sir Amias Paulet, the British ambassador to that court. His superior sagacity recommending him to the ambassador, he was sent home with an important message to the queen. On his return to Paris he devoted considerable time to examining the country, and collecting information on the characters and resources of the European princes; which information he arranged, at the age of nineteen, into a work *On the State of Europe.* In this early effort of inherent genius we have decided evidence of that depth of penetration, industry in research, and solid judgment, which, in later years, made him great among modern philosophers.

On the death of his father, by which he was left almost wholly unprovided for, he returned to England in 1579, and applied himself to the study of law and philosophy. In both of these departments of study he made great progress, and in June, 1582, he was called to the bar. Some of Bacon's biographers assert, that the dry details of legal investigation were unsuited to his lofty genius, and that philosophy, being more congenial to his spirit, attracted the largest share of his attention. This might be: and certain it is, that he studied philosophy with more than common assiduity; for when a student in Gray's Inn, he published a piece entitled *The Greatest Birth of Time,* in which his great work the *Organon* is sketched—yet he was by no means either careless or undistinguished as a member of the legal profession. In 1586, he was made a bencher, and at the age of twenty-eight, was appointed counsel extraordinary to the queen, besides receiving several other legal appointments in rapid succession.

Although connected with the most powerful family of Elizabeth's reign, Bacon's prospects of state preferment were considerably marred by the opinions entertained of his speculative disposition. His mind was too far advanced for the age he lived in, and his genius too original and gigantic to be appreciated by the men of his time. Hence he was looked on, to a certain extent, with an eye of suspicion, and the Cecils, with whom Bacon was nearly related, jealous of the zealous friendship which he had early evinced for their great rival the Earl of Essex, then in the decline, operated rather to hinder than advance the interest of Bacon at the court of Queen Elizabeth. All that the Cecils ever procured for Bacon was the reversion of the office of registrar of the Star Chamber, which, however, yielded him no emolument till twenty years afterwards. Essex endeavoured to procure for him the office of Solicitor-General; but failing in this, he made Bacon a present of Twickenham park, worth £1800.

Bacon's friendship for Essex was of a most sincere character. Notwithstanding the opposition of powerful relations, he attached his elder brother to the interest of this nobleman; and although a coldness subsequently ensued in consequence of a difference of politics, and the line of policy which Essex pursued, when ruin closed around the unfortunate Essex, Bacon still evinced the friendship of former years, and by application and entreaty to the queen, strove to avert the fate to which Essex was afterwards subjected. In virtue of his office Bacon had to appear as one of her majesty's counsel against his former friend. Instead, however, of attaching any blame to him for this, it must rather be considered a duty from which there was no escape, and which afforded opportunity of befriending the accused earl. The declarations of treason against the Earl of Essex, which Bacon had to draw up by command of the queen, were so far mollified by early friendship as not to suit the purposes of the earl's accusers, and caused the vindictive Elizabeth to remark, " I see old love is not easily forgotten."

In 1592, Bacon was returned to parliament for the county of Middlesex, and distinguished himself in the debates, by taking the popular side. From this time till the accession of James I., Bacon's pecuniary circumstances were very bad. He was twice arrested for debt, and failed in an attempt to form a matrimonial connexion to relieve his difficulties. He published several works on political and legal subjects, some of which have been characterized as too much eulogistic of his royal mistress.

Upon the accession of James I., Bacon received the honour of knighthood, and at this time his eloquence and information gave him great weight in the House of Commons. From the prudence and boldness with which he represented the oppressions of the royal purveyors, he received the thanks of parliament, and was appointed one of the counsel to the king. With the latter appointment he received a pension of £60 per annum. Notwithstanding the opposition of Cecil, now Earl of Salisbury, and the rivalry of Sir Edward Coke, the attorney-general, he continued to rise both in the royal favour, and the good graces of the nation at large. In 1605, he published " *The Advancement of Learning.*" Two years afterwards he was appointed solicitor-general, which office he fulfilled with distinguished success. His practice in Westminster Hall extended, and he received a large fortune by marriage with the daughter of Benedict Barnham, Esq., a wealthy alderman of London. His parliamentary labours still added to his popularity, without lessening his interests with the crown. Neither public nor professional labours, however, lessened the assiduity with which he pursued the study of philosophy. He published his " *Cogitata et Visa,*" which formed the groundwork of his " *Novum Organon Scientiarum,*" and sent copies to his learned friends for examination and criticism.

As the author of original ideas in philosophy, which run counter to opinions entertained for centuries, Bacon had considerable difficulties to contend with in enunciating his doctrines. He seems, however, to have been aware of this, and in throwing new light upon science, sought rather to illume than to dazzle, rather to awaken than astonish the mind. Besides, he had sufficient tact to perceive that for the successful promulgation of new opinions, it was necessary to establish a certain pre-eminence in the literary and scientific world; and this he effected by the publication of " *The Wisdom of the Ancients,*" and other works on subjects allied to the spirit of his age.

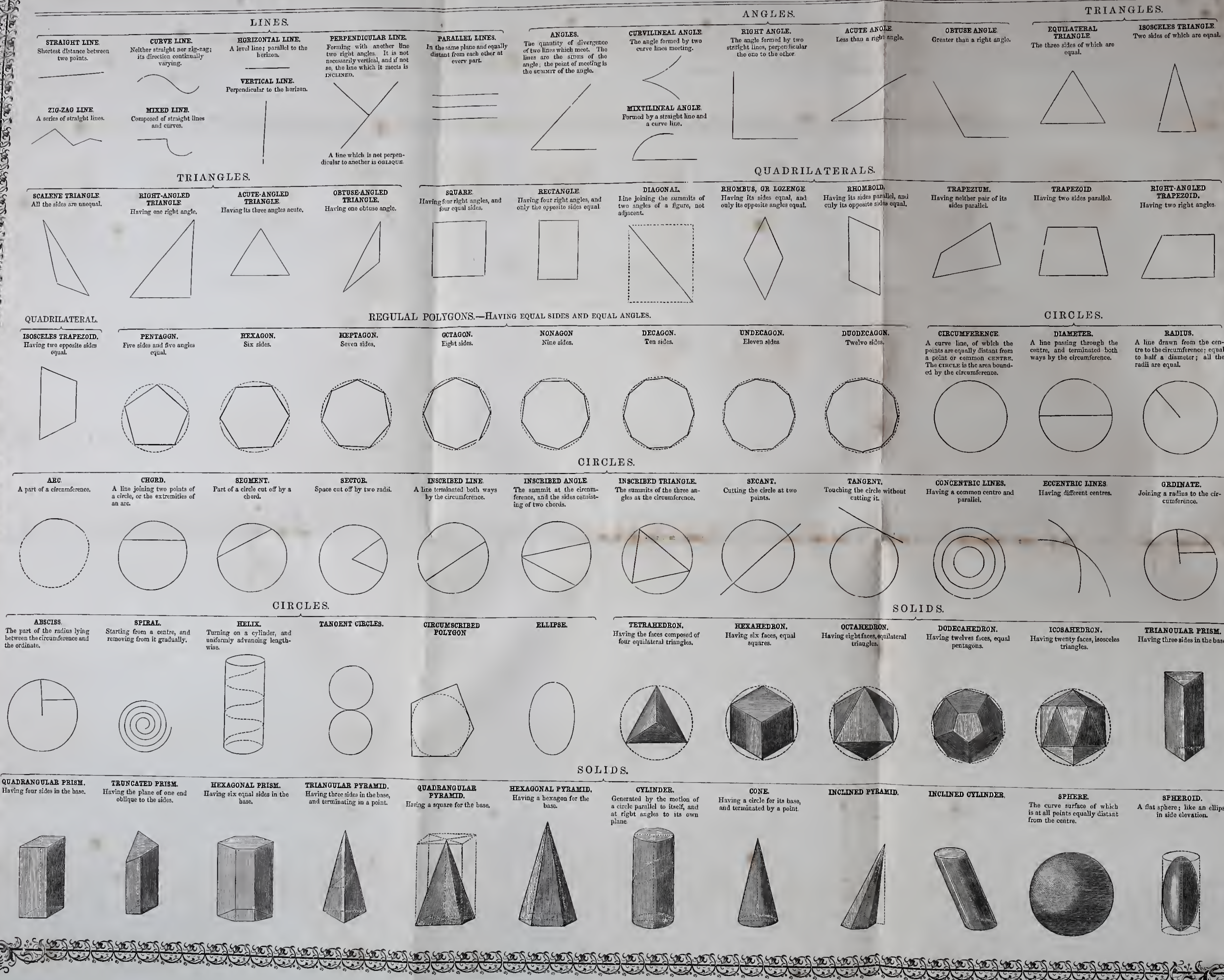
In the year 1611, Bacon was a joint judge of the Knight Marshall's Court. In 1613, he was appointed attorney-general, and elected a member of the privy council, and in regard to his great services was allowed to retain his place in the lower house. At this time his professional practice was great. The office of attorney-general yielded £6000 per annum; as registrar of the Star Chamber he received £1600; he had a good estate in Hertfordshire, and his father's seat of Gorhambury by the death of his brother; besides, he had the income of his wife's large fortune.

On the 7th of March, 1617, he was made lord-keeper of the great seal, and on the 7th of May following, he took office. Some political intrigues, and the use he made of the power conferred by this new office, in refusing to sanction the improvident grants of Buckingham, shook for a moment his stability at court. Prudence, however, re-established his footing, and on the 4th of Jan., 1618, he was appointed lord-high-chancellor of England, and by letters patent dated Wanstead, 11th July, 1618, he was created Baron Verulam, and took his seat among the peers. On the 19th of November, 1619, he got the farming of tho alienation office. Next year he was made Viscount St Albans. In the beginning of 1620 he kept his birthday with great state; and his virtues were celebrated in verse according to the fashion of the day by Ben Jonson. Bacon chose this favourable moment for tho publication of his *Organon.* This work he had commenced in his early years; and amidst the bustle of professional duties and the excitement of public life, he still went on for years, enlarging and improving, gathering experience in maturer years, and his opinions corrected or confirmed by extended research, and the opinion of the learned men of his day. Twelve times he is said to have rewritten this great work, correcting and revising, and at last when occupying the highest position of power and learning in his native land, he launched it into the world to earn from posterity the title given to its first outline, " *The Greatest Birth of Time.*"

The studies and efforts of Bacon were directed towards the clearing every branch of science, from the scholastic rubbish which for centuries had gathered around them, marring their development and application, and making the school of philosophy more the arena of unprofitable speculation and dispute, than the home of legitimate science. In his Novum Organum, he points out the true method of studying science. Grasping within his powerful mind the whole range of human knowledge known in his day, he investigates the relations of the various sciences, and attempts to arrange them according to what he understood as the faculties of the human mind. He divided the sciences into those of the memory, of the understanding, and of the imagination; and however imperfect this division is to be regarded at the present day, it betrayed an effort of no ordinary character, and tended greatly to facilitate the study of science. But the great merit of this work perhaps rests in laying down the im

# TABLE OF GEOMETRICAL FIGURES FOR PURPOSES OF GENERAL REFERENCE,

## TO ILLUSTRATE THE TREATISE ON PRACTICAL GEOMETRY.

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portant doctrine, that the only way to discover the truths of natural science, is *by observation and experiment.* But it was reserved for posterity to appreciate the genius displayed in the "*Novum Organon.*" It was the product of a strong mind, matured by reflection, but too lofty and original in its conceptions to be appreciated even by the learned of that time. Accordingly, when issued to the world, although it commanded the commendations of the few philosophers whose mind could comprehend its truth and value, it was assailed by the grossest and keenest ridicule of the wits of the time.

The life of Bacon, after this, is a melancholy exhibition of moral turpitude in the character of a great man. The easy circumstances which he enjoyed might have placed him beyond the reach of temptations. He is said to have been embarrassed by the rapacity of servants. But this can afford no palliation for the perversion of justice, which characterized the conclusion of Bacon's official career, which struck him down from his lofty elevation, and consigned him in dishonour to the grave. The charges brought against him were, malversation in office by taking bribes, and violating justice by his decisions in the court of Chancery.

On the 15th of March, 1620, Sir Robert Phillips reported for a committee appointed by the House of Commons, to inquire into the charges brought against the Lord Chancellor, and stated that two charges of corruption had been found tenable. To the sifting of these charges, the Commons directed their attention; and after much discussion, the case was referred to the House of Lords for their decision. Struck down by the discovery of his guilt, Bacon sent in a confession to the lords appointed to try him. This first confession, however, was unsatisfactory to the judges, who demanded an ample statement of the minute details of his crimes. With this Bacon complied, averring to a deputation sent to wait upon him, to inquire if the confession was a voluntary act, "It is my act—my hand—my heart: O my lords, spare a broken reed." He was stripped of his offices, disqualified for public life, banished beyond the precincts of the court, subjected to a fine of £40,000, and to be imprisoned in the tower during the king's pleasure.

After a short confinement in the tower he was discharged, and shortly after received licence to come for a time within the precincts of the court, and afterwards a pardon "for all the frauds, deceits, impostures, bribes, corruptions, and other malpractices of which he had been found guilty." He was even again summoned to attend parliament; but he scarcely ever emerged afterwards from the seclusion of private life, and the pursuit of scientific studies. Some friends he had still left, but he sought his chief consolation under public odium, and the stings of his own conscience, in the walks of philosophy. He published his works on Natural History, and a history of Henry VII., after his disgrace. From science he sought what enjoyment yet remained for him on earth, and from this he received his death. While making some experiments, the retort he was using burst, and the fragments struck him on the head and stomach; fever and defluxion ensued, and he expired in the house of the Earl of Arundel, at Highgate, on the 9th of April, 1626, in his sixty-sixth year, leaving no issue.

"The accomplishments of Lord Bacon were unrivalled in his day, and his character displayed the phenomena of great originality, combined with a most extensive range of acquirements. He was a poet and an orator, a lawyer and a statesman. In the philosophy of experiment and observation, he was pre-eminent; the metaphysical and the physical were both congenial to his genius, and although the taint of immorality has induced many to doubt the extent, and to depreciate the excellence of his knowledge and ability in every department, except his method of studying nature, an impartial and searching examination will fill us with admiration as we successively trace his steps in almost every branch of intellectual exertion." In his will he says, "My name and memory I leave to other nations, and to my own countrymen when some time be passed over."

## ILLUSTRATIONS OF MECHANICAL DRAWING.

Constructive Mechanics, as a branch of art, has, it is universally admitted, attained a high degree of perfection. The necessity for good and accurate workmanship has increased as the application of machinery to the manufacturing arts has extended. This necessity has led to the invention and construction of numerous tools for the purpose of finishing and completing the machines required. By means of these tools—themselves, some of them of exquisite workmanship—our mechanicians have been enabled to turn out machines of almost unsurpassable accuracy of workmanship, delicacy of finish, and functionary precision. It becomes then a matter of no idle curiosity nor aimless acquisition, but an accomplishment of real importance, to be able not only to form just conceptions of the nature and connection of the geometrical outlines of various parts in machinery, but likewise to be qualified to develope our conceptions so formed in visible delineations—in plain language to be fit to make out correct working drawings of machinery, on geometrical principles.

But while we use the term geometrical, let not our practical student be repelled from the farther study of this article, as if there were something unintelligible in the word. A geometrical form is simply a regular form, or a form of which the development is founded on some definite rule—a geometrical rule or law. A piece of lump sugar, casually broken from a larger mass of the same substance, or a clod of earth turned over by the plough, or the outline of the sea-coast, cannot be said to possess a geometrical form, in the ordinary sense of the phrase, because we followed no law of form in giving a separate existence to the former objects, nor can we recognise any regularity in the form of any one of the three. In each case, the form is rather a compound of a multitude of other forms equally irregular, thrown together in an irregular manner. In a more comprehensive sense, indeed, it may be affirmed, without contradiction, that the form of the clod, such as it is, has resulted from the recognised laws of gravity and cohesion, and must of course possess some definite relation of parts; but without being hypercritical and raising any argument on this point, which is really beside the question, every intelligent mechanic will understand the nature of the distinction, as regards form or outline, between *shapeless* masses of iron, earth, or loaf sugar, and the erect, square, and rounded mass of a steam-cylinder, or the precise exactitude of a spur wheel.

Again, to approach still nearer, by comparison, to the distinctive idea of geometrical forms, there are many forms which, while they are not geometrical, are nevertheless characterized by a simplicity, harmony, and grace, which set them at a wide distance from such rude forms as those we have been contemplating. We need only allude to the human form as a pre-eminent example of the distinct class of forms now alluded to. The simplicity of the human form is greatly owing to its being composed solely of curve lines; now, not only are straight lines excluded from the figure, but circular lines also, at least so far as that they never constitute any feature in the outline. In tracing the contour of the body in any given attitude, or from any given point of view, we no sooner arrive at an elevation or a depression which begins to assume a circular outline, than it sweeps into another curve either rounder or flatter than the one which precedes it, or of which the convergency may be reversed, so as to form an undulation. If we may be permitted to apply the language of geometry at all, we would say that the radius of curvature perpetually varies, and is frequently reversed, and that the utmost approximation to a geometrical analysis of the figure would be the remote generality, that it is composed of very short segments of circles, directly and reversely running into one another. That this definition is of no practical utility, however, is very evident from the fact that no one ever yet could delineate the human form on geometrical principles, as we dare say no one ever attempted it. He who could seriously set himself to accomplish such an impossibility would be scouted, pitied, or laughed to scorn.

It is not to be understood, however, that lines which lie beyond the definitions of geometry are invariably excluded from mechanical designs. On the contrary, they may be, and often are, introduced so as to produce very agreeable combinations of form. It would be inapt to quote the instance of a ship, for in this piece of work all geometrical lines are set aside. It is in fixed framework in machinery principally that variety of design is exhibited. It is possible, however, to indulge the taste for freedom of outline to a fastidious extent, as in the example of the locomotive-

engine tenders of certain builders, in which the contours of the coke-bunkers, recesses which are never exposed to view, are as carefully moulded to curves which no one ever saw before, and which could be converted into straight lines by an alteration of a hair's breadth, as if they were designs for fauteuils (easy seats) in the queen's travelling-carriage.

We may, on another occasion, follow out the train of thought suggested by the foregoing reflections, with reference to the principles of design in machinery. In the mean time, to cut short these preliminary remarks, we hope we have succeeded in assisting the student to understand what geometrical forms *are not.* It behoves us now to explain to him what geometry *is,* and to initiate him into such of the problems of geometry, as are necessary for his aid in the practical delineation of mechanical compositions. In approaching this introductory exposition, we mean to state and illustrate only such propositions as are of directly practical use in the delineation of all ordinary matters of mechanical design, to the exclusion of such as may safely be left to remain within the paste-board walls of Euclid. We utter this apparently irreverent sentence—irreverent towards the memory of the immortal Euclid—with the proviso that we speak of what is wanted only for the immediate necessities of the mechanical draughtsman, of what he cannot do without. We know from experience that many an artisan will consent to devote his attention to the acquisition of a few plain methods of doing a few plain things, when he would be effectually scared from the regular study of a system embracing the development of the principles of geometry. We heartily recommend the study of Euclid's elements of geometry to such as are able and willing to bestow upon it the leisure and application necessary for its prosecution, as they will thereby not only acquire a complete conception of the nature of the science, but will also provide themselves with a fund of general ideas on the relations of figure, which will, in many cases, be of very great advantage to them.

*Geometry,* then, is the science which treats of the properties and relations of *magnitudes,* that is, of things which have length, or length and breadth, or length, breadth, and thickness. The word is derived from two Greek words signifying *the earth* and *measure,* obviously embodying the idea of measuring the earth. Some more specific explanations, however, are required; and we shall now explain what are the *things* referred to in the definition.

A *solid* is that which extends in three directions; that is, which has length, breadth, and thickness. The application of these distinctive terms to the three dimensions of a body is simply a matter of convenience. In applying the reasonings of geometry to a solid, it does not matter though the solid were turned upside down, or round about; whether its thickness or height should exchange its name for its length, or its length under one aspect should be called its breadth under another aspect.

A *surface* or *superficies* is that which has only length and breadth. It may be called the boundary of a solid, as it has no thickness.

A *line* has only length without either breadth or thickness; and it may properly be distinguished as the boundary of a surface, the simple termination of it.

A *point* has neither length, breadth, nor thickness; it has simply position. For example, the intersection or crossing of two lines which pass through each other, is a point; it obviously has a position or locality, but cannot be said to have either length, breadth, or thickness. In like manner, the extremity of a line is a point; it terminates the line.

In attempting to represent lines and points on the surface of paper by means of drawing instruments, the representations can never more than approximate to the things intended to be shown. For the finest line that can be drawn, will have *some* breadth; and, indeed, if it had no breadth, it could not be visible. In the same way, a point may be represented by a very minute dot or puncture on the surface; still, as it covers *some* surface, it is not a geometrical point; it is only an approximation or something very near what is intended. Since, then, all material representations of objects on paper, by means of lines, are really only approximations in proportion to the fineness of the lines employed, those drawings will be the most correct in which the finest lines are employed, other circumstances being the same. It should be understood then, that the foregoing definitions are not without their practical value, as they set before the student the standard of perfection to which, if not really attainable, he should strive to approach as nearly as possible.

In studying the following definitions, the reader is requested to refer where necessary, to the accompanying Table of Geometrical Figures for illustrations of the objects of the definitions.

A *straight line* is the shortest way between the points constituting its extremities. Straightness is exemplified in the strings of a violin when screwed up into a state of tension. If a straight line were bent at particular points in its length, it would become a *series* of straight lines, termed in familiar language a *zig-zag.*

A *curve line* is one which continually changes its direction between its extremities. It is evidently not the shortest way between its extremities; neither is it a zig-zag, as this is composed of straight lines.

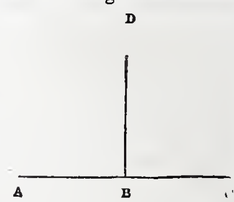
A *plane surface,* or *plane* simply, is a surface which contains the smallest extent of surface that can be enclosed by its boundaries. This is exemplified in the end of a drum, which, when screwed up or stretched into musical trim, is perfectly *flat,* as we would say in ordinary language. And it is clear that the shortest distance between any two points on the surface of the drum-end, must lie in that surface; that is, in general, if any two points be taken in a plane, the straight line which joins them will lie wholly in that plane. For illustration of this, if we apply a "straight edge" to the stretched surface of the drum, we shall find that it coincides with that surface, into whatever direction it may be turned.

A *curve surface* is one which is continually deflected, no part of it being a plane. The shell of an egg presents a curve surface, whether it be viewed externally or internally. The exterior surface of the superficies is denominated a *convex* surface, and the interior a *concave* surface.

*Parallel lines* are straight lines in the same plane, which are equally distant from each other at every part. They, consequently, never can meet, though produced or extended ever so far either way.

A *rectilineal angle* is the quantity of divergence of two straight lines, which either meet or cut each other at a point, without regard to the lengths of the lines. As there are numberless positions in which the lines meeting or intersecting, may be placed in relation to each other, so there may be numberless angles at which they may stand. These may be arranged into three classes—right angles, obtuse angles, and acute angles.

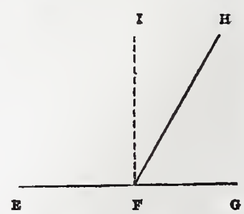
A *right angle* is formed by one line standing on another, so that the adjacent angles may be equal, *each* of these angles being a right angle. Thus the line D B, standing on the line A B C, forms with it the two angles at B; and if these angles be equal, then each is a right angle. Further, the line D B is called a *perpendicular* to the line A C, in virtue of its right-angular position.




Here we may shortly explain that, in designating an angle, we employ the letters used to denote its sides. Thus, the angle contained by the lines A B and D B, is called the angle A B D; and that contained by D B and B C is the angle D B C.

An *obtuse angle* is one which is greater than a right angle. Thus, if the dot-line F I be at right angles to the line E F G, the line F H, inclining to one side of the perpendicular F I, will form the obtuse angle E F H.

An *acute angle* is one which is less than a right angle. Thus the line F H, inclining toward F G, off the perpendicular, forms the acute angle H F G.




A *plane triangle* is a surface bounded by three straight lines. When three sides are all equal, it is termed *equilateral;* when two of them are equal, it is called *isosceles;* all other plane triangles are classed as *scalene* triangles. Any side may be called the *base.* Triangles are denominated also according to the magnitudes of their angles. When the three angles are acute, a triangle is called *acute-angled;* when one angle is obtuse, it is *obtuse-angled;* when one is a right angle, the triangle is named a *right-angled* triangle.

In a right-angled triangle, the side opposite the right angle is

called the *hypothenuse;* the other sides are called, indiscriminately, one of them the *base*, and the other the *perpendicular.*

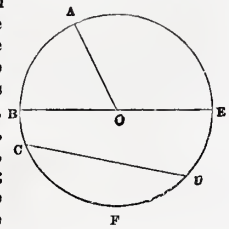
A *quadrilateral* figure is that which is bounded by four straight lines. When the opposite sides are parallel, it is called a parallelogram. When a parallelogram has right angles, it is called a *rectangle;* when a rectangle has all its sides equal, it is termed a *square;* when a parallelogram has no right angles, it is termed a *rhomboid;* when the four sides of a rhomboid are equal, it is termed a *rhombus* or *lozenge.*

A quadrilateral figure is termed a *trapezium*, when neither pair of its opposite sides are parallel. A trapezium, with two sides parallel, is called a *trapezoid.*

A *diagonal* is a straight line joining two angles of a figure, not adjacent.

Plane figures of more than four sides are called *polygons.* When the sides of a polygon are equal, it is a *regular* polygon; when they are unequal, it is *irregular.* The distinctive appellations of polygons, derived from the number of their sides, may be learned from the table, under the head of Regular Polygons.

A *circle* is a plain figure bounded by one curve line, called the *circumference*, and is such that the circumference, is at all points equally distant from a point within it, called the *centre.* Thus the curve line A E F in the annexed figure is the circumference; the area inclosed is the circle; the point O, from which lines O A, O B, O E, drawn to the circumference, are all equal, is the centre. Any line, as O A, drawn to the circumference, from the centre, is termed a radius; and a line B O E, passing through the centre and terminated both ways by the circumference, is called a *diameter.* The radius is, then, half the diameter.




An *arc* of a circle is any part of the circumference, as C F D.

A *chord* of a circle is a straight line joining any two points of the circumference, as C D, joining the points C and D.

A *sector* of a circle is the space cut off by two radii, as A O B, or A O E. When the radii are at right angles, the sector is called a *quadrant.*

A *segment* of a circle is the space cut off by a chord, as the space C F D, cut off by the chord C D.

A *semicircle* is a portion of a circle cut off by a diameter, as the space B F E, cut off by the diameter B E. This space amounts to half the circle.

A *tangent* to a circle is a straight line which touches it, meeting it only at one point, called the *point of contact.*

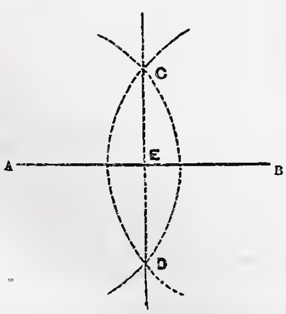
Of *solids* there are a great variety. As planes are bounded by lines, and derive their names from the character and dispositions of these lines; so solids are bounded by surfaces, either plane or curve, and derive their titles therefrom. Regular solids bounded exclusively by planes, cannot have fewer than four sides. A four-sided solid is termed a *tetrahedron.* A solid having more than four sides is a *polyhedron.* The specific titles of polyhedrons will be learned from the Table, which see also for the definitions of *prism, pyramid,* &c.

If the student has taken the pains to understand the foregoing definitions, he will proceed with pleasure to the study of the following problems and their practical solution.

Problem I. To bisect (or divide into two equal parts) a given straight line by a perpendicular drawn to it.

1. To bisect the given line A B, set one foot of the compasses on the extremity A as a centre; and with any convenient radius that is evidently greater than half the line, describe the arc C D, similarly from the point B as a centre, describe another arc with the same radius, cutting the first one at the points C and D.

2. Through the points of intersection C and D, draw a straight line C E D. This line will divide the given line A B into two equal parts, A E, E B, at the point E; and will also be a perpendicular to the line.




It is not necessary in practice to draw the complete arcs C D. An experienced eye can readily anticipate the points of intersection of the arcs, within small limits. Neither is it necessary to do more than apply a straight edge to these points of intersection, and tick the point E; unless indeed the perpendicular itself be wanted, which is often the case.

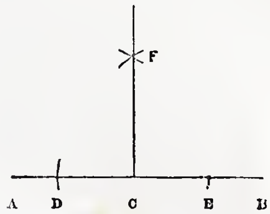
The same process serves for the bisection of a circular arc; for, supposing A B to be the chord of the arc, the perpendicular which bisects the chord will also bisect the arc.

Problem II. To draw a perpendicular to a given straight line, from a given point in that line.

*First.* When the point is near the middle of the line.

1. Let A B be the line, and C the point near the middle from which the perpendicular is to be drawn. On C as a centre, with any convenient radius, set off equal parts C D and C E on the line A B.

2. On D and E as centres, and with a longer radius, describe arcs intersecting at F, and, if wanted, on the other side of the line also.



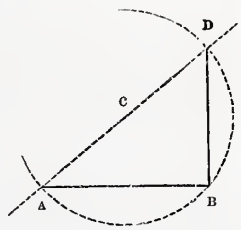

3. Draw the line F C. It will be a perpendicular to the line A B at the given point C.

*Second.* When the point is at or near one extremity of the line.

1. Take any convenient point C, obviously within the perpendicular to be drawn from the given point B, place one foot on C, and extending the other to B, describe a circle A B D, cutting the line A B at A.

2. Set a straight edge to the points A and C, and draw a line cutting the circle at D.

3. Draw B D, which will be the perpendicular required.




*Another Method.*—1. From the given point B, set off on the given line a distance such as B A, equal to three of any units of measure, as 3 inches, or 3 feet.

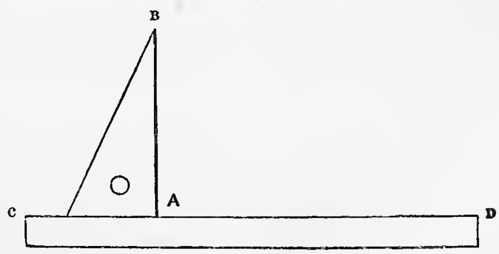
2. From B as a centre, with a radius of 4 of the same parts, describe an arc supposed to pass through D.

3. From A as a centre, with a radius of 5 parts, describe an arc cutting the other arc at D.

4. Draw D B for the perpendicular required.

This last method of solving the problem can be easily applied on a large scale for laying down perpendiculars on the ground. Timbers also may be set at right angles by the same method. The numbers 3, 4, and 5 are, it is to be observed, taken to measure respectively the base, the perpendicular, and the hypothenuse of the right-angled triangle A B D. Any multiples of these numbers may be used with equal propriety, when convenient; as 6, 8, and 10, or 9, 12, and 15, whether inches, feet, or any other unit of length.

When a series of perpendiculars to the same straight line are




required, they may, if not above six inches long or so, be drawn with ease by means of a straight edge and a triangle, after one of the perpendiculars has been found, by the foregoing method. Thus, one edge of the triangle A B being set to the perpendicular found, and the edge of the rule C D applied to the base, if the triangle be slid along the edge of the rule, its side A B will run parallel to the line to which it was set, and will consequently yield perpendiculars as far as the rule may extend.

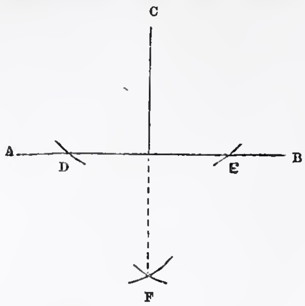
A similar application of the triangle and straight-edge enables

us to draw parallels to any given line. The method of using a couple of triangles for the same purposes has already been described.

PROBLEM III. To draw a perpendicular to a given line from a given point without the line.

*First.* When the point is conveniently near the middle of the line.

1. Let A B be the line, and C the point without it. On C as a centre, with a conveniently long radius, describe an arc cutting the line A B at the points D E.




2. On the points D E, as centres, and with a longer radius (the longer the more accurate the work is likely to be), describe the arcs intersecting at F.

3. Set a straight edge to the points C and F, and draw a straight line from C to the line A B. This will be the perpendicular required.

If there be no room below the line A B, the intersections F may be taken above, that is, between the point C and the line. This mode is not, however, so good as the one already described, because it is not likely to be so exact.

*Second.* When the point is near the end of the line.

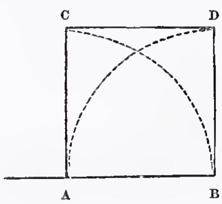
1. In the figure annexed to the second case of Prob. II., let D be the given point, and A B the straight line. From D draw any straight line D A, meeting A B at A.

2. Bisect A D at C, and on C as a centre, with C A as a radius, describe an arc cutting A B at B.

3. Draw D B for the perpendicular required

PROBLEM IV. To describe a square on a given straight line.

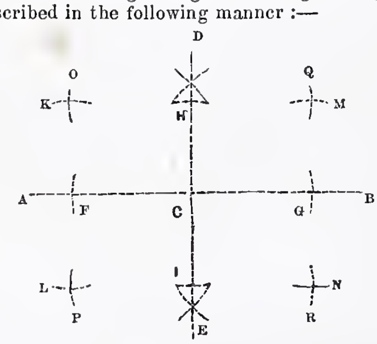
1. Let A B be the straight line, or the base of the proposed square. Draw A C and B D perpendicular to the base, from its extremities, and make each of them equal to A B.




2. Draw the line C D; this will complete the square A B C D on the line A B.

A rectangle may be constructed in the same manner. Having determined one of the sides, perpendiculars are drawn from each end of it, of the proper equal lengths, and their extremities joined.

When the centre line of a rectangle is given, the figure may be very accurately described in the following manner :—




1. Let A B be the centre line, and C the middle of the length of the figure. Draw the perpendicular D E through the point C.

2. Set off C F and C G, on each side, equal to half the length of the rectangle.

3. Set off C H and C I, on the line D E, each equal to half the breadth of the rectangle; with the same radius, and from the centres F, G, describe arcs K, L, M, N.

4. From the intersections at H, I, and with the half-length as radius, describe arcs O, P, Q, R, cutting the others. The four lines joining the extreme points of intersection will constitute the rectangle.

PROBLEM V. To draw a line parallel to a given line.

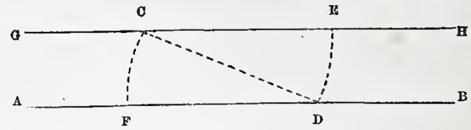
*First.* To draw the parallel at a given distance.

1. Let A B be the given line. Open the legs of the compasses to the required distance, and from any two points O and D (the farther apart the better) describe two circular arcs on the side towards which the parallel is to be drawn.

2. Apply a straight edge tangentially to the arcs, at E and F,


and draw the straight line G H; this will be a parallel to the given line.

*Second.* To draw the parallel through a given point.



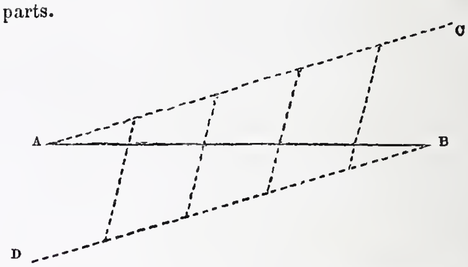

1. Let C be the point; from C draw any oblique line, C D to A B.

2. From C and D as centres, describe arcs D E and C F.

3. Make D E equal to C F, and through the points C E, draw the parallel G H. This is the line required.

The methods of describing squares and rectangles, already given, are also available for drawing parallels; though they are not so generally ready of application as the foregoing.

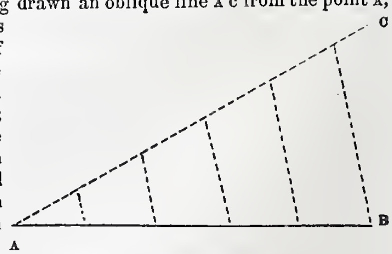
PROBLEM VI. To divide a straight line into any number of equal parts.




1. Let A B be the straight line, to be divided into, say, five equal parts. Through the points A and B, draw two parallels, A C, B D, forming any convenient angle with A B.

2. Take any convenient distance, and lay it off four times (one less than the number of parts required) along the lines A C and B D, from the points A and B respectively; and join the first on A C to the fourth on B D, the second on A C to the third on B D, and so on. The lines so drawn will divide A B into the required number of equal parts.

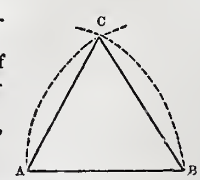
With the assistance of the straight edge and the triangle, or a couple of triangles, this process may be considerably expedited. Thus, having drawn an oblique line A C from the point A, lay off five equal parts on it; set the edge of the triangle to the point B and the fifth graduation on A C; slide the triangle parallel to itself in the direction B A, and draw parallels from the points of division on A C to the line A B; the latter will thus be divided into five equal parts.




PROBLEM VII. To construct an equilateral triangle.

1. Let A B be the length of the side of the triangle. On A and B, as centres, describe arcs cutting each other at C.

2. Join A C and B C; the triangle A B C, thus formed, is equilateral.

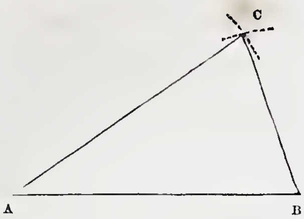



PROBLEM VIII. To construct a triangle, having its sides of given lengths.

1. Let A B equal the base of the triangle. On A, as a centre, with a radius equal to one of the sides, describe an arc.

2. On B, as a centre, with a radius equal to the third side, describe an arc, cutting the former at C.

3. Join A C and B C. The triangle is thus completed as equired.

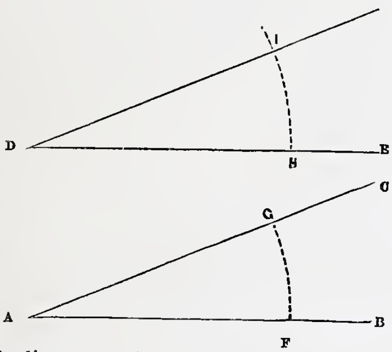



This problem is useful in enabling us to locate a point, the distance of which from two other points is known. Thus the position of the point C is readily ascertained by the foregoing process, when its distances from the points A and B are given.

PROBLEM IX. To draw a straight line so as to form any required angle with another straight line.

1. Let B A C be the given angle, and D E the line upon which D an equal angle is to be drawn at the point D. From the points A and D, with any convenient radius, describe arcs F G and H I.

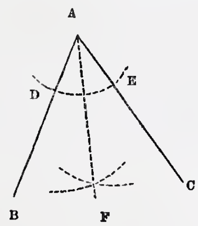
2. Set off the length of the arc F G contained between the lines A B and A C, upon the arc H I; and draw D I. The angle E D I will be equal to the given angle B A C.




PROBLEM X. To bisect a given angle.

1. Let B A C be the given angle. On A, as a centre, describe an arc, cutting the sides of the angle at D and E.

2. On D and E, as centres, describe arcs cutting each other at F. The line A F will bisect the angle, as required.




These foregoing problems are among the simplest of the kind, requiring for their solution only the use of straight lines and circular arcs. We shall, in our next chapter, finish the subject of geometrical problems, involving examples of greater complexity than those just given, and clearing the way for something more practical.

## COAL FIELDS OF GREAT BRITAIN.

### CHAPTER I.

#### COAL FORMATION OF THE WEST OF SCOTLAND.

THE carboniferous formation (1) of the Scottish Lowlands extends from coast to coast, forming from north-west to south-west, a belt about 40 miles in breadth, and 80 in length. Through its whole extent it is much dislocated by faults (2) and the protrusion of trap rocks, nor can any of its characteristic beds be traced everywhere through the coal area. The deposits of which it is composed occur in troughs or basins (3), generally separated from each other by a curvature in the external or internal features of the country, or by the occurrence of trap ranges. These troughs, basins, or hollows, contain in general a number of coal beds thick enough to be worked, interstratified with layers of sandstone, clay, clay shale, and ironstone. Some of these basins or troughs contain only the older strata (4) of the coal formation, but the larger basins generally contain both the nower and the older.

The coal beds vary from the thickness of a few inches to 9 feet or more, and the sandstones and shales are often 30 or 40 feet thick. The sandstones contain stems and trunks of trees of unknown genera, and sometimes though very rarely shells. The shales abound with the shells of both marine and fresh water genera of extinct species, and also with the scales, bones, teeth, vertebræ, and fins of fishes, all of extinct genera. These also occur abundantly in the ironstones.

The traps or whinstones occur in overlying masses, or in dykes (5), which penetrate the strata generally in a slightly inclined or vertical position in the form of a wall. These masses and dykes are of igneous origin, and have flowed from beneath towards the surface in a liquid condition. They have the effect of altering the strata to a certain extent on either side, sandstone being much indurated, and coal deprived of its bitumen, and reduced in many instances to a cinder. These traps or whinstones never contain any remains of plants or animals. The faults of the coal fields are upheaves or downthrows, by which the distance of a bed or series of beds from the surface, is altered according to the extent of the dislocation.

The carboniferous formation of the Scottish Lowlands may be divided into the

1st. Upper red sandstone series.
2nd. The upper coal series, in which the organic remains indicate a fresh-water or estuary origin.
3rd. The upper marine limestone series.
4th. The lower coal series.
5th. The lower marine limestone series.
6th. The lower sandstone series.
7th. The Balagan and Levenside limestones.
8th. The old red sandstone.

#### UPPER RED SANDSTONE.

The upper red sandstones may either be regarded as belonging to the age of the new red sandstone of England and the continent, or simply as a portion of the coal formation. The last view is certainly the more correct one, as it contains both beds of coal and coal plants. These it is true are rare, but this is always the case in rocks where the red oxide of iron is present in considerable abundance, as is the case in this formation. Generally speaking, its upper portion may be described as an aggregate of red and reddish-coloured sandstones, occasionally variegated with shades of green, purple, and yellow. These sandstones are either massive or laminated micaceous (6). They alternate with red and variegated shales and marls. In a bore made near Hamilton, where the red sandstone formation probably attains its greatest thickness, there were found about 40 fathoms of rocks preserving the red colour. Below this there were found thick beds of white sandstone alternating with a few thin seams of coal, clay shale, and micaceous laminated sandstones. In this formation, conglomerates (7) are rare, the only instances we witness being two, one in the bed of the Calder, near Broom-house toll, and another of a brecciated character at Hamilton; but the red sandstone beds frequently contain nodular masses of a concretionary character (8), which, from their containing a considerable portion of the carbonate of lime, are more indurated; when they have become subject to the action of water they stand out in relief. The red sandstones overlie the coal in Ayrshire, over a great area; those in Lanarkshire, and as far as our opportunities of observation go, possess nearly the same lithological character. The position of the red sandstone to the upper workable coals is much nearer than in Lanarkshire, except in one or two instances, where the red colour prevails below the 1st, and even the 2nd workable coal. Where this is the case, the coal is destroyed as if it had been acted upon by heat. The case we allude to, is a pit at Rosehall in the parish of Old Monkland, in the shanking of which the sandstones were observed of a reddish colour, so far down as the third workable seam of coal, being about 80 fathoms lower in the vertical section of the coal field than it is usually observed. It has always been to us a matter of astonishment, why the strata of one period should be characterized by such an abundance of the per-oxide of iron.

while in the older or newer strata, that mineral was either diffused in layers or nodules of ironstone of a grey colour. It is worthy of remark also, that a thin stratum of clay ironstone which usually lies above the splint or 5th coal of the upper series, and always found of a light fawn or grey colour, was in this pit almost quite red.

One important fact to be derived from the phenomena stated, is that though red rocks are seen to prevail in certain localities, it is not to be concluded, because at certain places, 50 fathoms of white sandstone, grey faikes, and blue shales, intervene between it and the workable coal seams, that such is always the case. Another geological conclusion to which it leads is this, that the red sandstones overlying our coal beds have no claim to be ranked as belonging to any other period than that of the true coal era.

Neither are the upper red sandstone formation of the counties of Lanark or Ayr known to possess any mineral, except the sandstone of the slightest value for economical purposes. Red ferruginous layers are met with, but not in such quantities as to offer any inducement to the miner. The coals are also of an inferior character; "scarce half made up," and never exceed from a foot to twenty inches in thickness. The upper red sandstone of Lanarkshire occupies an area, measuring in its greatest extent from east to west, about six miles, and from north to south, from three to five miles. It is traversed by the faults common to the coal measures, in both Lanarkshire and Ayrshire; but it is in the latter only, where whinstone dykes occur in the upper red sandstone, as well as in the regular coal measures.

That the coal formation in Arran is either represented by an eminence, deposition of sandstones, and conglomerates, or immediately succeeded by such deposits, must be evident to all who have examined the structure of that island. These, like the red sandstones of Ayrshire, are traversed by whinstone dykes. Nowhere in Lanarkshire, where the upper coal series is fully developed, have we ever been able to find whinstone, which could be recognised as of newer date than the 4th or 5th workable coal seams, a circumstance which has often induced us to think that the greenstones of the coal fields are of nearly contemporaneous origin with these coals. It might, perhaps, be venturing too far, to consider the greenstone dykes affecting the lower portion of our coal fields in Lanarkshire, and those which pass through the red sandstones in Ayrshire, as contemporaneous; if this were the case, the red sandstones of Ayr are of older date than those of Lanarkshire. But this supposition cannot be considered as improbable, seeing that even the limestone containing the productio hemispherica, one of the lowest beds of the carboniferous series, is almost immediately succeeded by red sandstones on the opposite coasts of Arran.

☞ (1) The carboniferous formation, comprehending all the various seams of coal. (2) Breakages in the regular seam, formed by the protrusion of rocks, by the elevation or depression of the rocks beneath, and other causes. (3) Troughs or basins, as their name imports, are extensive hollows in which the coal seams are generally found; the hollows above the coal being filled up by the superimposed matter, are little perceivable in the general surface of the country. (4) Strata is a geological term for layers or beds of rock, &c., of which the crust of the earth is composed. (5) Rocks which have been thrown up from below, and breaks through the coal seams, are called dykes. (6) Formed of thin layers or plates, and containing mica. (7) Conglomerates are fragments of different rocks united together by some substance, as clay or limestone, originally soft, and afterwards hardened. (8) Round pieces of substances which have hardened together.

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## UPPER COAL SERIES.

The upper coal formation is of more limited extent than the under, but the depositions are much more regularly distributed over the areas in which they occur. This remark applies particularly to the valuable strata of coal and ironstone found in it. It contains no beds of limestone. The sandstones are neither so thick nor so good as those which occur in the older or newer strata: they are generally of a whitish or grey colour, and sometimes spotted red or yellow from the oxidation to which the stone has been subjected. This is almost always the case where a portion of the rock is in contact with the superincumbent alluvium (1). The sandstones are frequently granular, and when so, occur in layers, divisible by joints, and cleavage, into rhomboidal masses. Flagstones occur in some places of good quality; they are slightly micaceous; when the mica (2) increases in quantity, the layers split into thin laminæ, and are useless. These graduate into a slaty carbonaceous shale, known in the west of Scotland by the name of Faikes, which again, by insensible degrees, passes into clay-shale with scales of mica: this again becomes darker and darker in the colour from the presence of carbon, till we have bituminous (3) shale; which again as insensibly passes into cannel coal, or carboniferous (4) (black baud) ironstone, as carbon or iron prevail, or are mutually associated, forming what may be properly denominated a shale ironstone.

The ironstones are either carboniferous or clayey in their composition; in either case they commonly contain in weight about 30 or 33 per cent. of the metal. The superiority of the black-band ironstone is, that it contains a sufficiency of carbonaceous matter to *calcine* it, and when calcined (5), is free from the clay contained in the other. The mixture of both ores, however, in the furnace, tends to improve the quality of the iron.

The coals of the upper coal formation, if their developments in different localities are taken into account, are above thirty in number; seven or eight of these, however, are all that are workable, the rest seldom measuring more than eighteen inches, a thickness below which a coal seam ceases to be valuable. The coals are divisible into soft cubical coal, splint coal, smithy coal, blind coal, or anthracite (6), and cannel, or parrot coal. The first of these, the cubical coal, is preferred for household purposes, being, when pure, capable of producing intense heat. Splint coal, as the name implies, is divisible into horizontal plates, which, when laid open, show a frost-work like appearance of carbon. We have no evidence from the plants which occur in immediate contact with the coal beds, that the difference in the structure of coal is any way owing to the plants of which it was formed being of a different sort. The difference must have, therefore, arisen from the character of the agency which produced the conversion of the ligneous matter into coal: whether that existed in the acid produced in the process of decomposition, in the medium of deposition, or in the electrical agencies to which it was probably subjected, it is difficult to say. We have seen a coal-bed completely spoiled when in contact with a very indurated sandstone. The effect being quite similar to that produced by the proximity of trap; a circumstance in favour of the supposition, that the electrical or magnetic fluid has exerted a powerful influence in effecting the different modifications of the various rocks, particularly coal.

Cannel coal is a compact substance, containing a greater quantity of inflammable matter than the other varieties. It occurs in both the Ayrshire and Lanarkshire upper coal series, but is not found of such good quality as that of Lesmahago, which is connected with the lower coal formation.

Smithy and blind coal are found only where the trap exists; the action of which has expelled the bituminous matter, and reduced the mass to a more carbonaceous state.

The minerals mentioned constitute the strata of the coal formation. They occur in no determinate order, if it be not this, that coal generally rests on a stratum of soft shale (7), denominated *daugh*, in which vegetable impressions are peculiarly abundant, a circumstance which has been supposed to favour the theory, that the coal beds are laid on the same spot where the plants grew from which they were derived; a hypothesis also strongly corroborated by the ripple marks observable in the adjacent strata; these denoting the presence of shallow water. Such a hypothesis is certainly attended with great difficulties, but as plants are frequently found in coal strata, in the vertical position in which they grew, and coupled as this is with ripple marks, we think the balance is in favour of the subsidiary hypothesis (8). The extensive area that some beds are known to occupy, measuring many square miles, and the great uniformity preserved in their thickness through the whole extent of that area, seems fatal to the supposition that the wood was drifted from a distance. Indeed we are quite unable to conceive, under any possible condition, such vast collections of drift timber as would have been requisite. "Coal," says Mr M'Laren, "was analogous in its origin to common peat, and each bed was most probably formed on an extended surface of marshy land, covered by a rank vegetation. The finest coking coal Mr Hutton considers as a crystalline compound, whose constituents had been in a state of solution, but slate coal and cannel coal often bear distinct impressions of plants. The new method of cutting minerals into

slices so thin as to be transparent, of which Mr Witham has made so happy use, has been applied to coal; and by examining these with the microscope, the vegetable structure has been detected where no external trace of it was visible. In cannel coal, it exists throughout the whole mass, while the fine coal retains it only in small patches, which appear as it were entangled mechanically. Among other indications of the ligneous origin, tubes have been discovered filled with a resinous matter, which is the most volatile part of the coal, being what is first driven off by heat. All coal had therefore originally existed in the state of plants or trees. About three hundred species have been found in the sandstones and shales of the coal measures, and the greater part of these probably exist in the coal itself, though the tenderness and opaqueness of the material render it difficult to detect them by examination. The three hundred species are all extinct; about two-thirds are ferns, the others consist of large (9) coniferæ, (allied to the fir or pine,) of gigantic lycopodiaceæ(10) and of palms. The plants indicate a moist climate, as hot as that of the tropics; and this holds true in the coal plants, not only in England, but at Melville Island, within the polar circle. Dr Hutton thought that the vegetables had been carbonized by heat; but Dr MacCulloch contends, and that on good grounds, that the change has been effected solely by water and pressure; and that by these agencies, peat is capable of conversion into coal."

The entire thickness of the upper coal series of Lanarkshire, including the upper red sandstones, is about 260 fathoms; a proportion of this enormous mass consists of finely laminated (11) clays, derived no doubt, from the mud of former rivers. If the depositions of these were regulated by circumstances any way analogous in their nature and effects, to those of existing rivers, we can arrive at no other conclusion, but that the time required for their accumulation was immense. This is further proved by many of the beds containing through their whole vertical extent, casts of fresh water shells of all sizes. Some of these occur in shale in the state in which they lived, the hinge of the shell being always upmost; where they form beds, they lie horizontally in the most confused condition—one generation having lived after another, till a stratum measuring sometimes a foot or more in thickness had been deposited, consisting almost exclusively of their shells. The blackband ironstones contain these shells in abundance, as also the impressions of plants with the scales and bones of fishes.

We shall give a more particular account of both the Ayrshire and Lanarkshire seams and mussle-band: as also of the nature and distribution of the ironstone beds, in the west of Scotlaud, in our next chapter.

☞ (1) *Alluvium.* Sand, gravel, or clay, deposited in the older rocks. (2) *Mica.* A simple mineral, having a shining silvery surfaee, and capable of being split into thin elastic leaves. (3) *Bituminous.* Containing bitumen or mineral pitch, the substance to which coal is principally indebted for its inflammability. (4) *Carboniferous.* Containing carbon, the principal ingredieut of wood or coal. (5) *Calcined.* Roasted to a cinder or powder. (6) *Anthracite.* Coal deprived of its bitumen, and having a shining lustre like black lead. (7) *Shale.* Indurated slaty clay. (8) The hypothesis which supposes that the strata referred to was formed under water, and left bare by the subsidence of the waters. (9) *Coniferæ.* An order of plants, which, like the fir and pine, bear cones or tops in which the seeds are contained. (10) *Lycopodiaceæ.* Plants of inferior organization to Coniferæ; some of which they resemble in foliage, but all the recent species are infinitely smaller. They are called club-mosses in England, and grow principally on mouutainous heaths. (11) *Laminated.* Occurring in thin leaves or plates.

## NATURAL PHILOSOPHY.

### CHAPTER II.

#### MATTER AND ITS FORCES.

WHERE knowledge is vague, we rarely find that it occupies the intellect alone; it has a hold upon the imagination, and the language it employs has generally in it something of vagueness and superfluity. But, as it becomes exact aud intellectual, we must have respect to the precision of our terms; for although most of the language of philosophy, like most of its principles, are in common use, it is necessary for the accuracy of description, that the terms we use should have their meanings precisely fixed, that all confusion of ideas, and all ambiguity of sense may be avoided. Our subject—*matter and its force*—affords some opportunity of exemplifying this precisiou of terms, and of enforcing distinct notions of their import in the investigations upon which we are about to enter. We shall, indeed, consider this subject, on account of its manifest importance, at some length, although at the hazard of being thought "dry and technical."

What is the meaning of the expression *matter and force?* There is nothing, perhaps, in the whole range of our experience —not to say science—of the reality and existence of which we are more thoroughly convinced, but which is, in language, more inexplicable, than the notion which is conveyed by these terms. When we press our hands together, we are conscious of an effort made and resisted; and here is a first notion of force; and, when we see a body in motion, we feel convinced that force has been somewhere or other exerted. Our first knowledge of matter is conveyed to us by our sense of touch—a consciousness of resistance in the objects with which we come into contact impresses upon us a conviction of their *materiality*, of their *extension*, and their *impenetrability;* that is, their power to exclude everything of the same kind from being in the same place. Matter and force are, therefore, to be described rather than defined; they are known to us only by their sensible effects, aud their properties are what it behoves us to investigate.

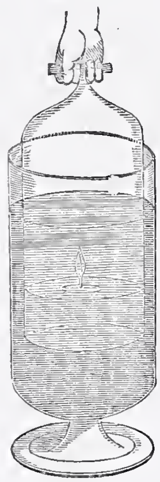
What do we know of *matter?* What are its properties? The old philosophers invented the word *substance*, to signify the framework of material things, and believed that all the varieties which we recognise among objects, rested upon this as the basis. The yellow colour of gold, together with its weight, hardness, and other properties, did not, in their opinion, belong to the substance, but rested upon it, while the substance itself was invisible, inscrutable; and, in a word, they did not know what it was, nor could they prove its existence, any more than they could prove the existence of another imaginary thing called matten, which they said had length, breadth, and thickness; though nobody ever pretended to have seen or felt this fanciful thing called matter, apart from wood, stone, metal, and the like. Even the strong inductive philosophy of Bacon, and the plain common sense which it has diffused, have not succeeded in banishing altogether the fanciful views built on these hypothetical nothings; and accordingly we find some nicely refining writers translating the old notion of substance into *essence;* and even the same meaning is forced upon the term *nature.** With this abstract notion, then—a notion which only exists in the mind, and cannot be shown to exist—we have nothing here to do; and, besides, we must not mistake the history of suppositions, for the knowledge of facts. Our inquiries are concerned with the materials which fill space. With this we connect the notion of quantity, and that kind of quantity too, which can be measured or estimated by some effect capable of being accurately appreciated by experiment or observation. We may, therefore, consider any common property of material things, and subject it to this test of measurement.

The first property which is usually named as essential to matter, is *extension;* that is, length, breadth, and thickness; and it is obvious that we can have no notion of a substance without this property; for length, breadth, and thickness, are the dimensions of extension, and they apply generally to the globe we live on, and a grain of sand; to the distant star of the heavens, and the glass of the telescope which it is seen through; to the cable of a ship, and the fibres of which it is composed; and, in fact, to every body in nature; and further, the relations of these dimensions are what constitute *figure*, or form. But with all this, extension cannot be regarded as a property of matter, separate from its *impenetrability*, unless we conceive that it can occupy space, without excluding other bodies from it. All that is meant by this long word, *impenetrability*, is, that no two particles of matter can, at the same instant, occupy the same identical portion of space. All bodies equally prove this property; and, indeed, were substances penetrable, instead of impenetrable, one substance might be successively absorbed by another, atom into atom, till the universe collapsed into a single point—till, in fact, it was annihilated. This occupancy of space is indeed the most complete idea we have of material existence; aud perhaps M. Pouillet is

* Rennie's Alphabet.

right, when he says, that it is only another name for matter. It may, however, appear, from the use we make of the term in common language, that there must be some sorts of matter in which this property is not found. Every one readily sees that one billiard-ball cannot be pushed into the substance of another, and that a piece of iron will retain its portion of space; but are those bodies which yield to the touch, as liquids and gases, impenetrable? If water, for instance, had not this property, there would be no such article as a force-pump, and Bramah's press, with its vast power—a power equal to millions of pounds—would never have existed. But still more familiar cases occur; for no heavy body is plunged into water, without displacing its bulk of the fluid. Thus, if an orange be immersed in a vessel full to the brim, exactly an equal bulk of the water will flow over. In the same way, when the foot sinks in clay, or a nail is driven into a piece of wood, there is no penetration, though we use the word in popular language; the whole resolves itself into displacement. The clay yields to the foot, and the fibres of the wood are crushed aside by the nail, but no atom of these bodies is penetrated; and we must recollect, that the term refers to the absorption of one particle by another, not to a reduction of the distances between them, or the relative places which they may occupy.

The impenetrability of air may be proved by means equally simple; and, indeed, the fact is perpetually before our eyes. If a quantity of it be allowed to escape under water, it rises through the water in bubbles, every one of which displaces its bulk of the liquid as it passes through it, in its way to the surface. If a tumbler be inverted, and pressed from air into water, the water does not rise far within it, because the air resists; and if it be inverted over a burning taper, made to float on the water, the taper will continue to burn, and the experiment will give the idea, in miniature, of the diving-bell, with its living inmate, at the bottom of the deep.



It may occur to the reader, that although impenetrability be admissible as a general property of matter, with regard to matter of the same kind, that there are cases when penetration does appear to take place. There are mixtures, for instance, in which there is an actual diminution of bulk. Thus, a pint of sulphuric acid (oil of vitriol), and a pint of water, when mixed, make less than two pints. The same is true, if spirit of wine be used instead of the acid. Facts of this sort are explained upon chemical principles, but we may still satisfy ourselves that there has been no loss of materials; the mixture weighs as much as the two liquids did separately, and we can readily separate them by distillation. The subject will also be more easily understood when we have considered the constitution of matter.

Another property of bodies is their *divisibility;* that is, their capability of being divided into parts. There are few substances that we have not seen bearing witness to the existence of this property, and astonishing illustrations of the extent to which this division may be carried, are found in many departments of the arts. Thus we know that 376 grains of gold can be hammered into 2000 leaves, each $3\frac{3}{10}$ inches square, and consequently not exceeding the 282,000th part of an inch in thickness. The coating of gold upon silver wire, termed gold lace, and used in embroidery, is still finer. The manufacture of this is effected by gilding a rod of silver, weighing 360 ounces, with two ounces of gold. This rod is then wire-drawn, till it is reduced to a thread, so fine that 1,200 yards of it weigh about an ounce. This wire is now flattened, by passing it between rollers, under severe pressure, a process which increases its length to 4,000 feet an ounce. Here we might follow out the calculation: every foot of this wire is equal to the 4,000th part of an ounce, and reverting to the original quantities, the coating of gold which covers an inch of it will be the 8,640,000th part of an ounce. Again, this inch is divisible into 100 equal parts, every one of which will be distinctly visible without the aid of any microscope; and the portion of gold which covers it is the 864,000,000th part of an ounce. Now, the five-hundredth part of this quantity will be a visible portion if examined by a good microscope; but we forbear to write the result. We might cite numerous other instances of a like character; we might refer, for instance, to the firmness of the micrometic wires for telescopes; to Dr Wollaston's contrivance for drawing the wire to the 30,000th part of an inch in diameter; and we might select parallels for them from among the filamentous productions of nature. We might mention, also, how "a grain of musk will scent a room for twenty years, without losing the millionth part of its weight," and that "there are living beings visible to the microscope, of which a million millions would not make up the bulk of a common grain of sand, and each having an organization as complicated as an elephant or whale." (?) In fact, they are

———— so wondrous small,
Were millions joined, one grain of sand would cover all;
Yet each within its little bulk contains
A heart which drives the *torrent* through the veins.

It may be a good arithmetical problem to calculate the magnitude of that heart—of the parts that compose it—of the globules of blood that flow through it—of the veins and arteries which convey the "torrent" through the animated particle—but to attempt to describe this "infinite littleness" would be useless expenditure of time and language. We might easily fill pages with examples and calculations relative to the subject; but the facts really give no tangible information concerning the general properties of matter, and this is the subject which in the meantime interests us. It must be admitted, however, that the contemplation of such matters is attended with intense interest. The vast gradation of animal life downwards, till the powers of our microscopes are exhausted, suggest to us the limited extent of our knowledge, as cogently as do our attempts to scan the boundaries of space itself. Does not our situation somewhat resemble the animalculæ we find in a glass of dirty water in a warm day? Their life is but a few hours, and they, in all probability, look upon the limits of their habitation as the boundary of the inhabitable world. What can they know of man—of the earth—of the universe? In their abode they can behold nothing but the inevitable destruction of their own species, and when they look beyond it, nothing is perceived but a confused assemblage of immense objects, whose natures and whose motions are utterly inexplicable to their faculties. Let us look at the analogy: the planets, the stars, the comets, and perhaps an infinity of other bodies, that are far beyond the reach of our knowledge, manifest the existence of powers which we cannot comprehend. Confined to the globe of this earth, which is only a speck in the universe, and with respect to us, not much better or worse than the glass of dirty water is in respect to its inhabitants, how insignificant our powers, and how limited our knowledge, when we would attempt to grasp the whole, and comprehend the plan—the *theory* of universal nature! In this sublime inquiry, the assistance of our reasoning faculty is small indeed; the clue of analogy is short and imperfect, and our imagination soon loses itself in the boundless extent of immensity.

It might be expected, before quitting the subject, that we should advert to the mathematical notion of the infinite divisibility of matter; but the subject is both barren of interest and utility. It is, indeed, to modern chemistry that we are to look for proper information on the elementary constitution of matter; and the phenomena with which this science is conversant, at once demonstrate, that while the divisibility is limited, the atomic particles of which it consists are far, far beyond all our means of measurement.

The deductions of that science tell us, moreover, that all material things are *indestructible;* that the ultimate particles of matter, however widely they may be diffused, are not individually destroyed or lost, but may again be collected into a body, without change of form. All cases of sublimation and distillation are instances of this; and when bodies suffer decomposition or decay, their elementary particles, in like manner, are neither destroyed nor lost, but only enter into new arrangements or combinations with other bodies. It is, indeed, to the growth and decay of animals and vegetables that the earth owes its fertility. These are reared on its surface, and when they have served their purposes, and death seizes them, the process of decomposition begins, and the elements go to the nutriment of other orders of organized beings. Thus there is a perpetual change from death to life, and from life to death, and a constant succession of the forms and places which the particles of matter assume. Nothing is lost, not a particle of matter is struck out of existence; and as nothing is lost or annihilated, so it is probable that nothing has

been added, and that we ourselves are composed of particles of matter as old as the creation. In time we must, in our turn, suffer decomposition, as all forms of matter have done before us, and thus resign the matter of which we are composed, to enter into new forms and new existences.*

Another property of matter, which seems to be essential to it, is *inertia*. This term means *inactivity* or *passiveness;* but its signification in philosophy will hardly appear plainer by the translation. It has been introduced from the circumstance that we are familiar with matter in two states:—in a quiescent state, and in motion; but it is a leading principle—one which will more plainly appear on due reflection—that no particle of matter, and no assemblage of particles, no body, in fact, simple or compound, possesses within itself a power of changing its existing state, whether of rest or motion. With regard to rest, there exists no difficulty:—when we are told that a stone will continue to lie on the ground till it is moved from it by some extraneous power, the mind at once assents to the proposition; for it is conformable to all observation. No body was ever found to give itself motion, or to pass from a state of quiescence without an impulse; but it requires some reflection to convince ourselves that when motion is once communicated to a body, it would continue for ever to move unless stopped by some external power. Observation seems to contradict this part of the proposition; for we know of no motion on the surface of the earth that comes not to an end, unless force be applied not only to produce but maintain it. But it will at once be admitted as a fact of universal experience, that the progress of a body in motion is retarded, precisely in proportion to the obstruction which it meets with in its way. A ball, which is rolled along the ground, soon ceases to move, but it rolls much farther upon ice—and why? because less obstruction is offered to its progress by the smooth surface of the ice, than by the greater roughness of the ground. And if we continue in imagination to reduce the impediments which the ball has to overcome in its motion, we cannot help at the same time to suppose that it will move farther and farther as the resistance lessens. Now what are the impediments in the way of a perpetual motion? We have no surface which is *perfectly* smooth: that is, produces *no* friction; in the next place there is the resistance of the atmosphere, which can never be excluded from any great space. When this is excluded, and the friction greatly reduced, the effect of an impulse is very remarkable. A common top, for instance, set in motion in the exhausted receiver of an air-pump, will continue to spin for hours; and a pendulum set in motion under the same circumstances, will swing for a whole day without the aid of clock-work; and why?—because there is nothing to resist the perpetual motion but the small friction at the point where it is suspended. But we have cases before us where air and friction are wanting, and the most appropriate instances too of perpetual motions, in the moon and planets. The motion there is unresisted, and we know that it is the same now that it was 2000 years ago.

The generality of this property of matter may perhaps be suspected, on the grounds that man and most other animals have the power to move themselves from rest, and to stop moving, independently of any extraneous force. Although it is here to be observed, that we do not pretend to apply the doctrine to animated bodies; in fact inertia is the quality usually given as the distinguishing characteristic of mere matter from life; yet we might extend it even to this case. For, be it observed, the animal receives a certain and general impulse at the commencement of existence; and all his actions, as long as he exists, are the consequence of that original impulse. The clock, for instance, when it is wound up, will continue to move its pendulum for a whole week, and at the end of every hour it will strike a certain number of strokes upon its bell. It is evident likewise, that those motions of the pendulum and hammer are owing to the original impulse which was communicated to the machine by the person who wound it up; yet a person, for the sake of quibble, might say, if bodies cannot put themselves in motion, or stop of themselves when they are actually in motion, how does it happen that the striking part of the clock puts itself in motion, and then stops itself when it has told its hour? The answer is familiar to every one who understands the mechanism of a clock. And what is true of such a machine, may in some measure be said of the more complicated mechanism of the animal body. But though we are led by the analogy of such simple movements, to admit the dependence of animal and vegetable motion on an original impulse, we do not presume to explain the origin, dependence, and possible modifications of that impulse: our knowledge of the structure helps us little in comprehending the nature and laws of that original energy.

The *quantity of inertia* is a phrase of frequent occurrence in all parts of physics, and it is necessary that it should be rightly apprehended. It is constantly proved by our experience, that it not only requires the exertion of a certain force to put matter into motion, and to take away that motion when it is once communicated; but further, that to give the same motion to different masses requires the exertion of different degrees of force. The quantity of inertia of a body may thus be estimated by the *quantity of force* necessary to put it in motion at a given rate; and hence one body is said to have as much inertia as another, if the impulse is capable of communicating to it the same velocity: if, again, it requires twice or thrice the force to make it move with the same speed, the body is said to have twice or thrice the inertia of the other. But the circumstance, that different quantities of force are necessary to communicate the same velocity to different bodies, has connexion with another circumstance—the *quantity of matter*. This is another phrase of frequent occurrence, and which is readily understood, on the supposition that all bodies are made up of material particles, and that the greater the number of these which we have to move, the greater will be the resistance which it will be necessary to overcome in communicating motion to the whole. The *quantity of inertia* is therefore the practical measure of the *quantity of matter* of a body; and accordingly two bodies are said to have equal quantities of matter, when they have equal quantities of inertia. The word *mass* as applied to bodies is synonymous with the term *quantity;* and accordingly we have such phrases as the *mass of matter*, and the *mass of a body:* these imply nothing more than the *quantity of matter* in the body.

We have already indicated that our idea of *force* is derived from observation. We are conscious of a power within ourselves to overcome a certain amount of the inertia of material things. We, for instance, can project a stone from the hand, and the body thus set in motion carries a force with it, which we feel in arresting its progress. We recognise a similar power of generating force in other animals by opposition to our own; and discovering that its seat is in the muscles, we denominate it the *muscular force*. This force is exerted by the animal at will; and, communicated to inanimate matter, it becomes sensible. But we learn in our experiments on the application of this force, that it is opposed not only by other animal force, but by certain forces appertaining to inanimate matter. When we lift a stone from the ground, we are conscious of opposition: and as whatever opposes force must be force, we are at once made conscious that the stone possesses this quality as well as ourselves. If the force we apply be greater than the force opposed to us, the stone is raised, and we familiarly term the resisting force *weight*. All our experience goes to show that this force is common to all material things. But to arrive at a just notion of it, we must examine the circumstances.

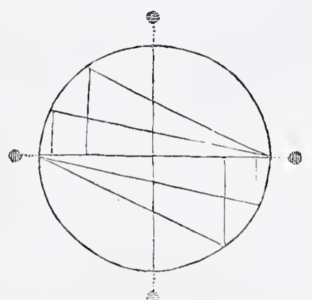
It is our uniform experience, that all detached *heavy* bodies, near the surface of the earth, move straight towards the surface and fall upon it. A brick set loose from the top of a building, or an apple from a tree, obeys this law; and it is the measure of this disposition to fall that we call *weight*. A little more close attention convinces us that any two masses of matter placed at any distance from each other, and uninfluenced by any external force, move towards each other, as if each possessed a certain virtue by which it was capable of drawing the other towards it. This is indeed familiarly illustrated by the fact that logs of wood floating in a pond, the wreck of a ship, and ships themselves in a calm sea, come together, and afterwards remain in contact. But it is further found, and the experiment is more satisfactory, although more delicate, that two metallic balls, when suspended by long cords so as to hang near each other,

* Comstock's Philosophy.

exert a mutual *attraction* over each other, so that neither of the cords is exactly perpendicular. On the same principle, it has been found that a plummet suspended near the side of a mountain inclines towards it, as was ascertained by the well-known experiments of Dr Maskeleyne, near the mountain of Schehallion, in Scotland.

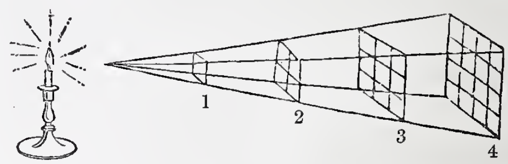
In all our experiments on this attractive force, two facts are uniformly perceived :—

*First:* The effect of the attracting force increases as the quantities of matter in the bodies increase ; so that in the case of the suspended balls, if one be double the mass of the other, the smaller ball will be drawn doubly farther from the perpendicular than the other. This may be roughly proved by placing two corks, one large aud another small, on the surface of a vessel of water : when they are brought within a certain distance of each other, they will rush together, but it will be observed that the smaller body moves more quickly than the other. If the same experiment be tried with corks of equal size, they will move towards each other with equal velocities, and will meet in a point equally distant from the points from which they began to move. This explains the fall of bodies to the earth ; its mass is enormous when compared with all the little bodies upon its surface. And viewing it as a hugely large ball, operating by its attractive force upon all the bodies which for an instant may be removed to a little distance from its surface, it makes these pass over, with very sensible velocity, the intermediate spaces, whereas itself remains apparently unaffected. It is in consequence of this enormous disparity, also, of the attractive power of the mass of the earth and of the bodies upon it, that the plummet line is not sensibly drawn from the perpendicular by every object in its neighbourhood ; and that it was only by the most accurate means which science could devise, that Dr Maskeleyne was able to detect the influence of the mass of Schehallion upon it. But it may be asked how it is that the plummet, in every situation on the earth's surface, gives a *perpendicular ?* This is nothing more than the familiar fact exhibited by all falling bodies—a fact which may be anticipated as soon as the law is known, that all bodies attract each other with a force proportioned to their masses. The figure of the earth is spherical, and we know that the longest straight line which can be drawn in a sphere from any one point of the surface to another point of its surface, must pass through its centre—it must in fact be a diameter. It is therefore obvious that the attracting force of the earth will operate more powerfully in this direction than in any other ; and hence the principle, that " all falling bodies tend towards the centre of the earth." This likewise explains the difficulty which commonly occurs to the young geographer, when he is first informed that the earth



is a globe, and that there are people living upon its surface, whose feet are towards his, and hence called *antipodes.* It shows that on every part of the surface of the earth bodies are attracted to it with nearly the same force (the slight difference arising from other causes to be explained hereafter). It further explains that *up* and *down* are merely relative terms, and that what is *up* with respect to us, is *down* with respect to our antipodes of New South Wales ;—*down* meaning everywhere towards the centre of the earth, and *up* the opposite direction. It accounts, in fact, for the spherical figure of the earth itself : for this force being inherent in the particles of which a body is composed, a number of these particles brought together will tend towards a common centre and arrange themselves, if free to move around it, assuming the spherical or round form. This implies, however, a state of fluidity, but this we know is not inconsistent with the facts of geology. The moon also is round, all the planets have the same form, and the sun itself is round—what is the inference ?—" that all must at one time have been to a certain degree fluid, and that all are subject to the same iaw." Drops of water on an oiled surface or on powdered rosin, globules of mercury, hailstones, a drop of dew on the end of a leaf, tears on the cheek, are all familiar illustrations of the same law of mutual attraction. The manufacture of lead shot is another example strikingly illustrative of the same principle. The lead is melted and poured into a sieve at the height of 200 or 300 feet from the ground ; the streams of lead, immediately on leaving the sieve, separate into round globules, which are cooled and solidified in their passage through the air, into the shot used by sportsmen.

*Second :* The energy of the attracting forco is increased in a certain proportion as the distance between the bodies is diminished : that is, the more closely bodies approach to one another, the more sensibly will they affect each other by mutual attraction,—just as the light of a candle or the heat of a fire is known to be more intense, according to the proximity to the source of the light or heat. That which is true of attraction is, indeed, in this respect, equally true of the action of all forces acting from a centre—that is, of all forces which emanate from a centre, and spread themselves round that centre ; and perhaps a reference to the diffusion of light from the flame of a candle will afford us the plainest illustration of the law. Common experience informs us that a taper radiates, or sends out its light, in all directions alike. Thus, if we place such a taper in the centre of a hollow globe, every part of the interior receives an equal portion of light. But with regard to the intensity of light which falls on the surface, we would observe a very remarkable difference, were we to make the experiment with globes of different diameters. The same is shown, however, without the complicated apparatus of globes ; for we readily perceive that what we have stated with regard to the equable diffusion of the light of a taper, holds with respect to the light thrown around a room by a candle placed upon a table in its centre. And suppose that we read at the distance of 1 yard from a candle so situated, and receive a certain amount of light on the book, and remove to the distance of 2 yards from the candle, we at once perceive that we have less light ; and if accurate comparison is instituted, we have little difficulty in believing that the intensity is only a fourth part of what it was in the previous situation. Further, if we remove to a distance of 3 yards, the intensity of the light will be found diminished to a ninth part of what it was in the first place : and if to 4 yards, it will be diminished to a sixteenth part, and so forth. We might here revert to the apparatus of the hollow globes, and show, geometrically, that such must be the law of diminution, but a simpler experiment will suffice. Suppose, in the annexed diagram, that 1 denotes the situation of a board of a




foot square, placed at a certain distance from a source of light at A, it will just shadow a board of 4 square feet at 2 ; that is, at double the distance ; a board of 9 square feet at 3 ; that is, three times the distance ; a board of 16 square feet at 4 ; that is, at four times the distance ; that is to say, the light which is concentrated upon the first board, will be diffused over four times the space, if suffered to fall upon the second ; over nine times the space upon the third ; or sixteen times the space upon the fourth. Taking the intensity of the light at 1 as *one*, its intensity at 2 will be a *fourth ;* at 3, a *ninth;* at 4, a *sixteenth:* it diminishes, therefore, as the surface of squares which shadow one another increases ; or, in technical language, *the intensity is in inverse proportion to the square of the distance from the centre of influence* (not from the surface). Now this is the law not only for light, but likewise for heat, sound, attraction, and every other influence from a central point. Accordingly, the attractive force at the surface of the earth, which is 4000 miles (nearly) from the centre, is four times more powerful than it is at 8000 miles from the centre. To make this plainer : suppose a piece of lead which weighs a pound, or 16 ounces, to be carried by any means 4000 miles beyond the surface of the earth, it would weigh only ¼ lb. or 4 oz. ; and if it could be transported other 4000 miles, that is in all 12,000 miles from the earth's centre, its weight would be diminished to 1-9th of a pound, or something less than 2 oz. And at the distance of the moon, which is 240,000 miles, that is

60 times farther from the centre of the earth than the surface is, our pound of lead would be reduced to the $\frac{1}{3600}$th part of a pound; or what will convey a clearer idea, 3600 lbs. would weigh just 1 lb.

The truth of this law has been severely tested, and we have now the utmost confidence in its predictions. We are able, for instance, to assert, that a mass of any given quantity will weigh more at the level of the sea than it will on the top of a mountain; and that its weight will gradually diminish if it be removed farther and farther from the earth's surface in a balloon; and farther, that it will weigh less at the level of the sea at the equaor, than it will at tho same level at any other point towards either of the poles, and simply becauso there is a difference of a few miles in the two diameters. All these facts havo been proved by experiment. It is to be remarked, however, that for all our ordinary purposes of weighing, the difference observable between the weight at the surface of the earth, and all distances from it which we can reach, is insignificant, though not inappreciable to the refinements of modern science. And farther, that even this refinod difference would not of courso be apparent in the usual manner of weighing by means of the balance; for tho decrease of the attracting force would affect both tho weight and the object, to be weighed equally; it may, however, be measured by a spring-balance.

Experience, reasoning, and analogy, prove that this reciprocal attraction exists, not only between the globe of the earth and the surrounding bodies on its surface, but betweon all masses of matter. One terrestrial body attracts anothor terrestrial body; the moon is attracted by tho earth, and the earth by the moon; the planets attract one another, and are all attracted by the sun; and probably tho great luminary himself, with all his planetary system, is attracted by some other object which astronomy may never discover. Wo may naturally be asked, how it is we know that the earth and the other planets are attracted by the sun? This is not the place to go into a complete answer to the question; still it may be stated in reply, that from accurato moasurements of the motions of the heavonly bodies, they are found to follow the same laws that bodies do which are projected in a certain manner near the surface of the oarth, and whose motion is undoubtedly determined by the power of attraction; we, therefore, according to our rules of philosophizing, attribute similar causes to similar effects, and conclude that the planets are attracted towards the sun, in the same manner as stones, water, and other terrestrial bodies, are attracted by the oarth.

Perhaps some of our younger readers may suppose that there are exceptions to this general rule of attraction. They see, for instance, smoke, steam, and other vapours fly away from the surface of the earth, instead of boing attracted to it, like a marble or a halfpenny when it falls; and they may therefore conclude that these matters have no *weight*,—which, it will bo recollected, is the measure we have of attraction. It was indeed formerly thought that smoke and steam were in their nature *light* or ascending—and we cannot therefore cavil at the objection; more especially as we cannot here fully meet it. But we may ask how it is, that if a cork, when dropped into an empty vessel, goes to the bottom, and when water is poured in, it ascends; or how, if it be forcibly sunk in the water and disengaged at the bottom, it ascends in the water with considerable rapidity? The answer will doubtless be that the cork is *lighter* than water, not that it has no woight. Now exactly the same explanation applies to tho ascent of smoke and the liko. It has been discovered that our globo of earth is surrounded by an ocean of air, having nearly 50 miles of height or depth—for *height* and *depth* are merely rolativo terms, like up and down—and that a cubic foot of it; that is as much of it as would be contained without compression in a box, whose sides, top, and bottom, are each a foot square, weighs about an ounce. It is then obvious that any substance which weighs less, bulk for bulk, must ascend just as the cork does in water, although not *light*, in the old sense of the word. All doubts of this sort will be met by and by; but, in the mean time, it may be farther observed, that smoke is sometimes seen to ascend majestically in a tall column; sometimes it rises but a short distance, and then spreads abroad on all sides; in both cases the air is heavier than tho smoke as high as it ascends perpendicularly, and then it meets with air of a density equal to itself and can ascend no higher. The fact is besidos easily proved by putting a candle under the receiver of an air-pump and exhausting the air: the candle will speedily be extinguished, and the smoke, which will afterwards be given off, will fall to the bottom as certainly as a piece of metal would. This proves that smoke has weight as well as other substances.

It may be here remarked, for the sake of accurate distinction, that when we conceive the weight of bodies to be produced by this force of attraction applied to each of their elementary particles, urging it downwards, that is, towards the centre of the earth, we give it the name of *gravity* or *gravitation*, or the *attraction of gravitation*. The accurate distinction, then, between gravity and weight is this: "the weight of a body is the product of the gravity of a single particle, by the number of particles." This, however, does not appear plainer than saying that the *weight* of a body is the measure of its gravity, and it is less practically expressed.

It must be farther observed, that there are several other varieties of attraction, as the *magnetic attraction*, which takes place between magnets and iron; the *electric attraction*, which is excited by friction between certain bodies, as silk and glass; *capillary attraction*, which causes liquids to rise in capillary tubes. These sorts of attraction and their phenomona will afford interesting matters of investigation during some subsoquent parts of our labours, but they belong not strictly to our present inquiries. Wo have already had occasion to consider briefly two other varieties of attraction, the *cohesive* and the *chemical*, ascribing to the first the power of aggregating particles of matter together in solids and liquids, and to the latter tho power of forcing the compound particles of compound bodies.*

Cohesion, from its mechanical importance, perhaps requires some farther illustration. Its degrees givo rise to the various densitios of bodies, and some others of their most interesting qualities. Wo have indeed been guilty of using tho term *density*, without porhaps conveying a precise idea of its meaning. If we are asked for a definition, wo must refer to our motion of the constitution of matter—to its structure as an aggregation of indivisible particles. This at once leads to the idea, that it must bo *porous*—must have empty spacos or *pores*, disseminated through its substanco, moro or less minute. A sponge, and open piece of wood, will occur to every one as instances of what are popularly called porous substances. These certainly oxhibit porosity on the great scale, though it must be remarked, that they contain pores which can only be detected by the aid of the microscope. But all substanees known are porous, even when no poros can bo discovered by the uso of magnifying glasses. The experimental fact, that all substances are more or less compressible, is, perhaps, sufficient proof of this. But recourse has been had to moro obvious experiments. For instance, the academicians of Florenco, ondeavouring to prove the compressibility of water, filled with this liquid a hollow globe of gold, and submitted it to groat pressuro: the result was, that tho water was forced through tho pores of the solid gold, and the globe perspired all over. This has since been repeated with other metals, and always with the samo result. The porosity of the human scarf skin is manifest from the important function of perspiration. Tho perspired matter finds its way outwards through pores only; yet those must be extremely minute, and consequently exceedingly numerous, when the quantity of matter thrown off in this way is considered. Some attempts have indeed been made to compute their number; but those, like calculations relativo to the divisibility of matter, are of littlo practical value. There is a species of flint called hydrophane in which the property is singularly manifest. This stone when dry is opaque, or rather translucent liko china; but on being dipped into water, this soaks into its pores as oil does into those of paper, and drives out the air which escapes in bubbles: when removed from the water, it is found to be one sixth heavier than before, and nearly as transparent as glass. In all these cases, the material named is not only porous, but the pores are at loast equal in size to the particles of water; for this passes into them.

With these facts before us, and tho inferences which they naturally suggest, there cannot bo much difficulty in understanding that one substance may contain more particles of matter in a given bulk than another, and this is our first idoa of density, whether we call it closeness of texture, or compactness of structure. They suggost, besides, the ready measurement of density; for of two bodies of equal bulk, that which is heaviest or weighs most is the most dense. But the size of the atoms is also a consideration.

* Chemistry, Chapter I., Arts. 16—28

To make this plain, suppose we assume any measure of bulk, and fill it with leaden bullets, we have a certain bulk or *volume* as we call it, of lead; but if small-shot be shaken among the bullets, the quantity of lead will be increased, but without any corresponding augmentation of bulk; the density then is augmented. This may be still farther increased, by introducing still smaller shot. This explains moreover in some measure how it is that a pint of spirit of wine or of oil of vitriol, and a pint of water, make less than two pints when mixed, and how nearly an ounce of dry culinary salt may be added to a full glass of water, without running it over.

"From many considerations, it would appear that the atoms even of the most solid bodies are nowhere in actual contact, but are retained in their places by a balance between attraction and repulsion." The principal facts which lead to such a conclusion are derived from a knowledge of the effects of heat on bodies and will be subsequently considered. But some evidence is also derived from the application of actual pressure. Thus we readily know that the density of air, steam, and the like, may be increased by mechanical force. Water and liquids in general resist compression very powerfully, but yield enough to show that their particles are not in absolute contact. For instance, water at the depth of 1000 fathoms has its bulk diminished; that is, its density increased by about a hundredth part, or 100 pints are compressed into 99. Solids, some at least, are subject to have their dimensions altered by forcible means. Most of the metals have their bulk diminished by hammering. "A weight placed on an upright rod, shortens it, and if suspended from the bottom, lengthens it—the rod in both cases returning to its former dimensions when the weight is removed."

In comparing the weights of equal bulks of different bodies, it is necessary to have some standard; and as water is easily procurable at all times, and in all places, it has been generally adopted as that standard. When a comparison is made, volume for volume, the result is termed the specific gravity. Thus, when we say that the specific gravity of platina is (about) 22, we mean that a cubic inch of it would weigh as heavy as 22 cubic inches of water. Similarly, gold is 19 times as heavy—mercury $13\frac{1}{2}$ times—lead 11 times—tin $8\frac{1}{2}$ times—copper 8 times, &c. This then is our practical method of expressing the relative density of different bodies. It is a subject which will occupy our attention at some future opportunity.

It might be expected that hardness would be in proportion to the density of the different bodies, but such is not the case. Glass, for instance, will scratch gold or platinum, though its density is much less. The quantity of hardness depends on the force with which atoms keep their respective places; but on what this atomic fixidity depends, does not well appear. Wherein for instance consists the difference between softened and hardened steel? We can scarcely hazard a conjecture; but perhaps the laws of crystallization will at some future date throw light on this subject.

There are two qualities of bodies which are usually cited as the opposites of each other: these are *elasticity* and *brittleness*. Now it may appear contrary to all experience to assert, that glass is an almost perfect type of both. But let us in the first place inquire into the meaning we attach to the terms, and this apparent contradiction will probably disappear.

Take in the first place *elasticity*. This might be shortly defined "the immediate resistance of a body to compression or extension;" but a clearer notion will be obtained of it from the popular explanation that it is the quality of a body, in virtue of which it regains its original state after compression, when the compressing force is removed. The presence of this quality is exemplified in the spring, as that which imparts the force. Different bodies exhibit it in very different degrees, and some are entirely destitute of it. It is said to be perfect, or rather bodies are said to be perfectly elastic, when the force of restitution is exactly equal to the force of compression. The aëriform bodies are all perfectly elastic, as is readily shown by compressing a bladder filled with air, and allowing it to expand again. The separation of two bodies, after striking together, proves elasticity. An ivory ball, dropped upon a marble slab, rebounds nearly to the height from which it fell, and no mark is left on either. To show that the rebound is in consequence of the yielding of the particles of one or both at the point of contact, the slab may be wetted, and it will be observed that a circular surface of some extent is marked on both; it is dry on the slab, and formed by a ring of water on the ball. A ball of glass, if the fall be not too great and break it, will exhibit the same effect: glass is therefore not only elastic, but perfectly so, for it takes no permanent bend; but unless in very thin plates, or in fine threads, it will bend but very little without breaking. The elasticity of liquids is seen at once from the rebound of a stone, and the like, from their surface; and from the way in which they rebound when poured from one vessel into another: their elasticity is perfect, but to a small extent. Indian-rubber is extensively elastic, for it yields far; but it is not perfectly elastic, for if stretched much, it remains permanently elongated. Putty, dough, and wet clay, are instances of the entire want of elasticity; and if any of these be thrown against an impediment, the form will be permanently altered.

All that is meant by *brittleness* is, that the body is easily fractured. It belongs chiefly to those bodies which have elasticity perfect, as far as it goes, but which is limited to a small extent. Glass, as already mentioned, is the type of brittleness, and we have referred to its elasticity. All crystallized substances are more or less brittle and elastic; and steel, when tempered so as to be very hard—and it may be made nearly as hard as diamond—assumes the same properties. Steel chisels, and other tools for cutting stones and metals, require, of course, to be exceedingly hard: they thereby become perfectly elastic; but the *extent* of their elasticity becomes very limited, and hence they are frequently broken. Brittleness seems to depend on the narrow limits within which the cohesion among the atoms rests, so that a very slight displacement causes fracture.

Softness, as we have seen in the case of the putty, dough, and wet clay, is accompanied by a proportional susceptibility of permanent alteration of form without fracture; sometimes, however, a soft body, for want of cohesion, is brittle. Soft substances which are capable of direct extension to a considerable degree, are called *viscous;* of these bird-lime, and sealing-wax, and glass sufficiently heated, are among the most remarkable. When the same exists in fibrous substances, we call it *tenacity;* and, in fact, we use this word to express all cases where force of cohesion is tried by longitudinal strain. Thus, the tenacity of steel wire is such that it will support above $7\frac{1}{2}$ miles of its own length, whereas iron-wire will only support about half as much, and lead wire only about the 35th part of iron-wire. Many parts of the animal system, as the ligaments and tendons, present the same property in a high degree, combined with elasticity and pliancy: these, indeed, when dried, formed the tough bowstrings of our remote forefathers. Stripes of intestines, prepared and twisted, form the cords of the harp and violin. Tenacity, applied to metallic substances, was formerly synonymous with *ductility*, but this term seems to be now exclusively used to designate a susceptibility of being drawn into wire. The properties, however, go together; and closely connected with them, though really distinct, is *malleability*, or the property which renders a metallic substance reducible to thin leaves by hammering. Of all substances gold is the most malleable. The instances of the thinness of gold-leaf already adduced are sufficient evidence of this. The ductility and tenacity of gold are however inferior to copper and iron. Silver, copper, and tin, are also malleable in a high degree, whereas most other metals break before the operation is carried far, and some with the first blow of the hammer. These qualities, malleability and ductility, are directly opposite to elasticity and brittleness. They seem to depend on the want of any fixed order of positions among the particles. These yield to force, and shift about among each other, as those of a liquid, without fracture, or change of property, or loss of cohesive force.

Another, and a universal property of matter, is *dilatability;* but this can only be entered upon in relation to heat. This, indeed, is one of the most powerful agents in changing and modifying the forms of matter, bringing about the states of solidity liquidity, and elastic fluidity, often in quick succession: we shall, therefore, next turn our attention to the investigation of the effects of that agent. We would also remark, that the phenomena of crystallization are so intimately connected with the chemical constitution of bodies, that we refer the subject entirely to the head of chemistry.

# CHEMISTRY.

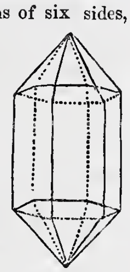
## CHAPTER II.

### CRYSTALLIZATION.

We have already had occasion to refer generally to the operation of that variety of attraction which we recognise under the general name of *cohesion;* but when we begin to examine more minutely into the results of this force, we speedily perceive that its operations are influenced by circumstances; and that mere aggregation of particles is not the only feature of interest which it presents.

A very slender acquaintance with the mechanical characters of solid bodies—with their internal texture, and external forms—reveals to us the fact, that the manner of aggregation is not the same in all. Sometimes the particles appear to cling together without order or arrangement, giving rise to irregular shapeless masses; but at others, we find them beautifully arranged, producing solids of regular and determinate forms. To these we give the name of *crystals;* and so important is the study of the forms and mechanical constitution of these bodies considered, that it now constitutes a distinct branch of science, under the name of *crystallography.*

If it is expected that we should define strictly what we understand by *crystal,* we would say that it is a solid bounded by plane surfaces, disposed in some particular manner, or, in the language of geometry, it is a polyhedron (many-sided figure), more or less regular. In all parts of the mineral kingdom, we meet with bodies of the form of polyhedrons, many, indeed, exceedingly irregular, but all bearing evidence of a law of formation, which it is the great business of crystallography to detect. Thus, all the precious stones are crystals, and can be well cut only parallel to their natural faces. The beautiful transparent substance called rock crystal (pure quartz) is found in prisms of six sides, terminated by summits of six plane surfaces, as shown in the accompanying figure. Common quartz differs from this only in exhibiting less regularity in its external forms, but the crystallization is essentially the same. Iceland spar, which is pure carbonate of lime, (the same in chemical composition as chalk, common limestone and marble,) is found in six-sided prisms also, but the opposite sides only are equal to each other. Diamonds occur in regular eight-sided forms (octohedrons); and the fluor spar of Alston Moor and Derbyshire, so much admired for its varying shades of blue and green, assumes (usually) the form of a cube; but in other parts the same mineral presents us with endless varieties of crystalline forms. Even the metals present themselves under geometrical forms. Native gold and silver, for instance, occur in small octohedrons, and iron and copper are occasionally found in cubes of great regularity. Silver and copper may be readily obtained in these respective forms by precipitation from their solutions, under certain circumstances, in the electro-chemical process which has obtained the indefinite name of electrotype. The crystalline texture of zinc, bismuth, and antimony, is well known, and readily seen on any of their fractured surfaces. The metallic ores are nearly all crystallized; and even mountain masses, like clay-slate, have a tabulated form. A piece of white marble presents a beautiful aggregation of minute crystals, and granite is an aggregation of crystals of quartz, felspar, and mica. But, in fact, throughout the whole of inanimate nature, we meet with traces of crystallization; and so generally is this manifested, that some writers have laid it down as an axiom, that "it is the disposition of all matter to form itself into regular geometrical forms, under the influence of the aggregating force."



But, notwithstanding this general "disposition," and it may appear remarkable, we meet with very few regular crystals among the productions of nature. If we are to account for this, it will be necessary, in the first place, to inquire into the conditions requisite to the complete development of the natural geometrical forms. Our first notion of the crystalline structure, is that of a spontaneous arrangement among the constituent particles of the solid so formed, by which the *manner* of adhesion of every particle is determined. But this implies, that in the act of aggregation, that is, while the particles are submitting themselves to be bound up by the aggregating force, that they have freedom of motion. Accordingly, the first step towards obtaining a substance in its crystalline form, is generally to produce this mobility of the particles; and this the chemist usually effects, either by solution in water, or by the application of heat. To take an instance of the former:—If we take a quantity of pounded nitrate of potash (saltpetre), and dissolve it in water, we obtain a solution in which the saline particles may be regarded as dispersed throughout the fluid, and having perfect mobility; but if the quantity of water be considerable, the particles will be too far asunder to exert reciprocal attraction: in other words, they will be more powerfully attracted by the water than by each other, and no aggregation will take place. When, however, we slowly abstract the water by evaporation, the saline particles are gradually brought within the range of each others' attraction, and finally become aggregated, producing regular solids, which, on examination, we find to be all of the same definite form, a six-sided prism. But if instead of withdrawing the water slowly, we hasten the consolidation, the crystallization takes place in a confused manner; and if the solution be continually agitated during the evaporation, we shall obtain a fine crystalline powder. It is by this latter process that nitre is prepared for the manufacture of gunpowder in France, instead of by grinding as in this country. Similarly a solution of sugar, when slowly evaporated and left for some time at rest, the particles arrange themselves in the well-known form of *sugar-candy;* but when the process is hastened, or disturbed, we have the confused crystallization of *loaf-sugar.* Common culinary salt, by analogous treatment, may be made to assume the form of regular cubes, and of the powdery form of basket-salt. The "*coarse*" salt, by the way, is generally the *finest,* if coarse and fine mean impure and pure.

In cases of igneous fusion, similar conditions are recognised: the melted substance must be slowly cooled, and, at the same time, undisturbed by motion. This is readily exemplified with any of the fusible metals, by a little management. If bismuth, for instance, be melted and allowed to cool again slowly, and at rest, it becomes solid first on the outside of the mass. If, then, before the cooling is completed, the remaining liquid portion be poured from within, the interior of the solid hollow mass will be found beautifully studded with four-sided pyramids, connected together at their bases. Crystals of lead, zinc, antimony, sulphur, and of some sulphurets, as those of bismuth and antimony, may be readily procured in the same way, more or less perfect, according to the accuracy of management. It may also be mentioned, that some other substances, when heated, readily assume the state of vapour, and, during condensation, present regular crystalline forms. The best examples of this are iodine, benzoic acid, camphor, and sal-ammoniac. In this way, also, crystals of snow are produced by cooling the aqueous vapour of the atmosphere.

Many crystals are met with in nature which cannot yet be formed by art, such as rock crystal, the diamond, Derbyshire spar, and many others; but analogy leads to the conclusion, that they are produced by the same species of operation as those which we can repeat in our laboratories. And if this be admitted, it is easy to see, from the nature of the conditions which are necessary to the complete development of the crystalline form, that these conditions will co-exist but very rarely; and hence we cannot be surprised that regular crystals are extremely rare, notwithstanding the generality of the so-called *disposition.* Almost all minerals present very irregular masses; but at the same time, they bear every evidence that this is to be attributed to the irregularity which presided over their formation. And besides, we must recollect, that most of them have, since their formation, been subject to the action of many extraneous forces, which it belongs to geology to describe.

Although few of the crystallizations that are performed by nature have been imitated by art, the subject is one of considerable interest to the chemist, who in his turn can effect the crystallization of a vast number of substances which are not found crystallized naturally; and, taking proper advantage of this circumstance, he is able to obtain them in a state of greater purity than any other method could afford them. To the chemist, also, the crystalline characters often serve as a ground of mechanical distinction between the different artificial products, as they do in

mineralogy to distinguish one mineral species from another. It is on this account, that we have introduced the subject here; but it is obvious, from the great extent of the subject, that we must limit our remarks to those circumstances which bear the closest reference to the pursuits of the chemist.

Most crystals which are formed from aqueous solutions retain a portion of that fluid: this is technically called their *water of crystallization.* Its proportions vary according to the nature of the salt which is crystallized. Thus, sulphate of soda (glauber-salt), and some analogous salts, contain considerably more than half their weight of water. This is readily seen by subjecting such a salt to a high temperature, when it will be observed to liquify in its own water, undergoing what is termed the *watery fusion.* Sulphate of lime (gypsum,) again contains about a fifth of its weight of water, which it loses at a red heat, and crumbles down into the white powder called plaster of Paris. This water appears to be in a state of chemical combination with the salt, and not simply interspersed as water through its substance: in almost all cases where it is present, the crystalline structure is destroyed when it is withdrawn. There are some salts, however, in which the affinity appears to be feeble: this appears true at least of those salts which part with their water of crystallization by simple exposure to a dry air, or *effloresce,* as it is called. In these cases, the crystals moulder away to powder, and entirely lose their peculiar characters and forms. Common carbonate of soda is an example of an efflorescent salt; and a similar effect is observable in the case of *barley-sugar.* There are again salts which manifest an opposite tendency: they *deliquesce,* or attract, water from the atmosphere when openly exposed. There are other salts again which form beautiful and transparent crystals, without combining any water of crystallization. Nitre, sulphate of potash, and common salt, are examples of this class. But it must be remarked, that although they do not seem to combine chemically with water, "they often retain it mechanically diffused in their pores." Salts of this class generally fly to pieces with a crackling noise, or *decrepitate* when heated. This has been referred to the rapid conversion of the retained water into steam, but it is more probably owing to the irregular expansion of the crystal: the outer layers being first heated, will expand and scale off.

Crystallization is sometimes determined in a solution, by apparently slight and almost inappreciable circumstances. A mere vibration for instance of the liquid, is often sufficient to commence the process. This is particularly remarkable in the case of water. This liquid, if kept perfectly at rest, may be cooled down considerably below the freezing point without consolidation; but under these circumstances, to touch the surface with the point of a pin, is enough to make the whole spring almost instantly into ice. In saline solutions, the introduction of a solid body—especially a crystal of the same substance, will cause the crystallization to commence; and the foreign body will form the *nucleus* or centre upon which it will take place, provided that body be capable of being wetted by the liquid. Manufacturers often avail themselves of this circumstance; and accordingly we have sugar-candy, acetate of copper (verdigris), sulphate of copper (blue vitriol), prussiate of potash, alum, &c. crystallized on threads, strings, twigs of wood and wires. Ornaments of these salts for grotto-work, &c. are readily made by introducing into their solutions a wire bent into the form wanted, and removing it when a sufficient quantity of the salt has been deposited upon it. As already remarked, crystals of the same substance as the dissolved salt are the best excitants; and in some instances, where there are two salts in solution, the introduction of a few crystals of the one, will readily separate them; that which is identical with the crystals introduced being crystallized, while the other remains in solution. For instance, if we dissolve two parts of nitrate of potash (nitre), and three parts of sulphate of soda (glauber-salt), in five of warm water, and fill two bottles with the solution, putting into one a crystal of nitre and into the other a crystal of the glauber-salt, only nitrate of potash will crystallize in the one, and sulphate of soda in the other. The process will be facilitated by placing the bottles in a very cold place, or in ice-cold water.

Atmospheric air seems to have its influence likewise in promoting crystallization in some cases, and of retarding it in others. For example, if we nearly fill a glass flask having a long neck with hot water, and add as much sulphate of soda as it will dissolve, and then boil it for a little time, and while the steam is rushing out (*having removed it from the heat however,*) close it accurately with a good cork, the solution may be cooled down in a quiet place without any symptoms of crystallization. But upon withdrawing the cork, the air will rush in, and the whole will crystallize almost instantly. Professor Graham—and most other chemists have agreed with him—ascribes this to the chemical union of air with the water, holding the salt in solution; but we must confess that the explanation does not seem to us to be more satisfactory than Gay-Lussac's, which refers the fact to atmospheric pressure. There are some salts again which can only be crystallized under the exhausted receiver of an air-pump: this, however, is in general owing to their changing their composition by exposure to the action of the atmosphere. Light also influences the process of crystallization. Thus, if a solution of the salt, called acetate of lime, be left to spontaneous evaporation, it will slowly travel in beautiful arborescent pellicles up the sides of the basin, and gradually proceed down upon the outside; but it will be remarked, that the process not only begins at the side most exposed to the light, but the arborescence continues always most copious on that side. The crystals collected in camphor bottles, in druggists' windows, are likewise observed invariably to be most copious upon the surface.

The mechanical characters of crystals are frequently modified very remarkably by the medium from which they are deposited, independently of any chemical change: thus, in foul and turbid solutions containing carbonaceous substances, the crystals are usually deposited of a larger size, and sometimes of different forms from those which are deposited from pure water; in gelatinous and saccharine solutions, the crystals are generally regular and sharp. In the manufacture of tartaric acid, this is particularly remarkable—the rough brown crystals of the first process being always larger and bolder than those of the pure transparent products of the last operation. It has also been observed, that common salt, deposited from an aqueous solution to which a small quantity of the animal substance *urea* has been added, crystallizes in octohedral instead of cubic forms. Beautiful and large crystals of iodine are deposited from its solutions in alcohol (spirit of wine). Very large artificial crystals, as specimens, may also be obtained by proper management, and sufficient patience, according to a process first pointed out by M. Le Blanc. The method consists in selecting very regular crystals of a salt, and placing them at equal distances in a saturated solution of the same salt. A regular deposition of fresh matter takes place upon the sides exposed; but the side which is in contact with the vessel receives no increase, so that they must be turned daily to preserve their regularity. After some time, the largest and most regular of these crystals are selected, and put separately into vessels filled with portions of the same liquid, and turned in the same manner at short intervals. By this treatment, they may be ultimately obtained of almost any size we think proper. But in trying the experiment, it must be observed, that as the quantity of salt in solution is continually diminishing, the liquid will, after a time, begin to act on the crystal and redissolve it. This action is first perceived on the edges, which become blunted, and finally lose their shape altogether. Whenever this re-solution begins to appear, the liquid must be poured off, and a portion of new liquid put in its place: otherwise the crystal will be infallibly destroyed.

When a crystallizable salt is perfectly pure, its solution continues to afford crystals by the common treatment, to the very last drop; but as all salts have a greater or less chemical action on each other, it often happens, that other salts or soluble matters are present in the same solution, and that after crystals have been obtained by successive evaporations and coolings, the remaining portion of fluid, though charged to saturation with saline matter, refuses to yield any more crystals. This residuary liquor, whatever may be the nature of its contents, is known by the general appellation of *mother water* or *liquor.* As it always contains a portion of the salt dissolved in it, it of course forms the best solvent for new matter of the same kind, which is to be crystallized; and it must be observed besides, that two or more salts which do not decompose each other, are together soluble in less water than is required to solve them separately: consequently, by using mother water as a solvent, not only the uncrystallizable material is saved, but less evaporation is necessary. This, however, it must be observed, is only applicable when the absolute purity of the material is not of importance, or as a first step in the process of purification. Where absolute

purity is required—and the chemists must always have a certain number of pure tests—several subsequent crystallizations may be absolutely necessary. But these are circumstances which will be noticed under the particular heads to which they apply, as will also any special directions for the management of particular cases of crystallization. In the meantime, we may lay it down as a rule, very generally applicable to cases of solution, that the evaporation should be continued until a *pellicle* forms upon the surface of the liquid : this indicates that the attraction of the saline particles for each other is becoming superior to their attraction for the water. The formation of this pellicle is therefore the common criterion of the fitness of the solution for crystallization : and where the regularity of the crystals is not a matter of importance, the evaporation may in general be conducted rapidly, and even somewhat farther ; but where it is an object to obtain very regular and very large crystals, the evaporation must be slow and carried to a much less extent : even spontaneous evaporation, or that which takes place at common temperatures, must sometimes be resorted to.

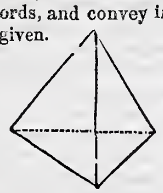
In describing the external forms of crystals, the surfaces which limit the figure are called *planes*, or *faces*. These are generally flat. The lines formed by the junction of the two planes are termed *edges;* and the angle formed by two edges is a *plane angle.* A point, again, formed by the meeting of three or more planes, is a *solid angle.* Their forms are commonly divided into *primitive* or *fundamental,* and *secondary* or *derivative;* and to convey distinct ideas of them, as shortly as possible, a systematic nomenclature, founded on the geometrical relations of the faces, has been introduced. For instance, crystals whose faces are *rhombs,* are termed *rhombohedrons,* and others, whose faces are *triangles,* are called *pyramids.* Again, when a crystal is contained under *four* faces, it is called a *tetrahedron;* when contained under *six* faces, it is a *hexahedron;* when contained under *eight* faces, it is an *octohedron;* and when under *twelve* faces, it is a *dodecahedron.* These names are formed of Greek words, and convey in themselves the explanations which we have given.

Triangle.

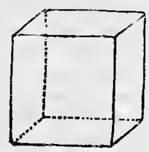
Rhomb.

The primary crystalline forms are reducible to the following:—

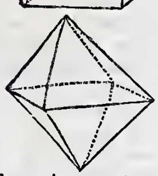
I. The *Tetrahedron.*—This form is contained under four equal-sided triangles. It is a regular solid of geometry, and the simplest pyramid which can be imagined. It occurs often in nature :—Example, copper-glance.



II. The *Hexahedron,* or *Cube.*—This form is contained under six equal square faces. It is a regular solid of geometry, and occurs very frequently in nature :—Example, iron pyrites.



III. The *Octohedron.*—This form is contained under eight triangular faces. It is a regular solid of geometry, and is very frequently met with in nature :—Example, cobalt pyrites, or grey cobalt.



IV. The *Dodecahedrons.*—These are contained under twelve equal and similar faces, the figure of which determines the kind of dodecahedron. There are two forms recognised as primary, viz ,—

1. The *Rhombic-Dodecahedron,* or the *Dodecahedron,* properly so called. The faces are twelve rhombs, as shown in figure 1. Fluor spar and garnet often occur in this form.

2. The *Trigonal-Dodecahedron.* — The 12 faces of this form are equal and similar triangles, as shown in figure 2. Some varieties of copper-glance and garnet-blende are found crystallized in this form.

*Fig.* 1.

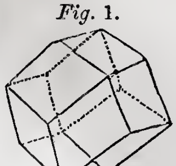
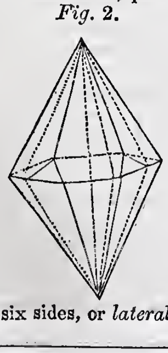
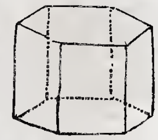


*Fig.* 2.



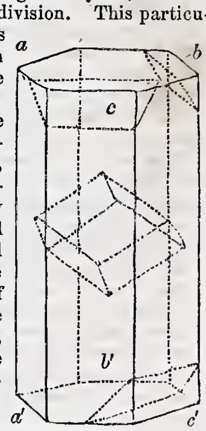
V. The *Six-sided Prism.*—This form has six sides, or *lateral faces,* and two *hexagonal* (six-angled) bases, or *terminal planes.* The mineral called *staurolite* often occurs in this form, and so does the Oriental ruby.



VI. *Parallelopiped.*—This name properly includes all those solids which have six bounding planes, and the opposite ones equal and parallel ; as, for instance, all the four-sided prisms, both right and oblique,* which do not possess the precise proportions of the cube.

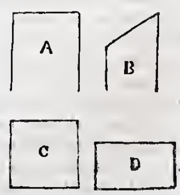
It is only in a very small proportion of cases that these forms are found complete : sometimes the edges and solid angles are wanting, and instead of them we find planes ; the edge is then said to be *replaced,* and the angle *truncated.* These, however, are merely terms of convenience ; for neither the edges nor angles ever were on the crystal, and therefore could not have been replaced, truncated, or taken off. "It seems as if the architecture of nature had been interrupted in midway ; but it is always obvious, that if the process had been continued, the perfect form would have resulted. Secondary forms may be conceived to be derived from the primitive intention, so to speak, checked in the original direction and forced into another." These truncations and replacements are sometimes so slight, as not to alter the *general* form of the crystal ; but they are often sufficiently deep to give it a perfectly different figure. For instance, if all the eight angles of a cube (II.) be conceived to be sufficiently truncated, and replaced by as many triangular planes, the figure of the cube will be completely obliterated, and a secondary octohedron (III.) would be formed. These passages of one form into another are constantly found occurring : it was indeed this circumstance which originally suggested the distinction of primitive and secondary forms.

It is here to be observed, that the undisturbed cohesive force not only determines the symmetry of the crystalline forms, but confers upon them an internal *structure,* which is equally regular. So remarkable, indeed, is this, that it has led to the inference, that all crystals are composed of molecules of certain geometrical dimensions, no less definite than the sensible solids which they compose ; and further, that the structure is determined by the particular arrangement of these definite particles. This arrangement is not immediately apparent to the eye, and conjecture alone can extend to the forms of the imperceptible molecules of which a crystal is built up. The consequences of the arrangement is, however, easily rendered obvious, and, indeed, is often brought prominently before us by the rudest methods. If, for instance, we examine a piece of calcareous spar (carbonate of lime), we find that it may be readily divided in directions which produce only one particular form ; and the number of these forms which may be extracted from the original crystal, is limited only by our means of mechanical subdivision. This particular nucleus, or form of crystal, is what is strictly understood by the *primitive* form of *crystal,* and the lines of fracture are denominated *cleavage.*




To illustrate this fully : suppose we take a complete crystal of this spar, and attempt to split it with the edge of a knife, we find that of the six edges of the superior base, three *alternate* edges only will yield—those, for instance, marked above by *a, b, c*—and the division will take place in a plane inclined at an angle of 45 degrees. On trying the edges of the inferior base, we find again that the intermediate edges alone yield ; namely, those marked *a', b', c';* and if we continue this dissection, we at length obtain a crystal, which has the figure of an obtuse rhombohedron. This is shown in its relative

* The term *oblique prism* is employed to designate one in which, supposing the lateral planes to be held perpendicularly, the terminal planes are not at right angles to them as in fig. A ; but are joined obliquely, as in fig. B. It may be observed, also, that there are four-sided prisms which are not square prisms ; the term *square prism* implies that all the opposite perpendicular planes are of the same width ; when this is not the case, but the opposite ones only are of the same width, the form is called a *rectangular prism.* The terminal planes of a square prism are of course squares, as shown in fig. C ; and *parallelograms,* in the rectangular prism, as shown in fig. D.



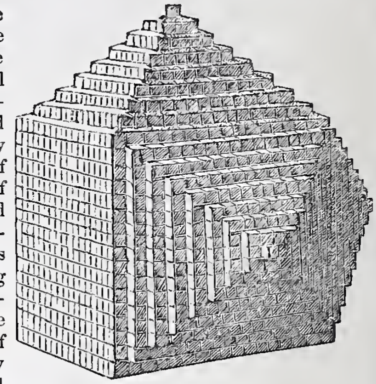
situation to the including prism, and is the primitive or fundamental form of the calcareous spar. Whatever crystal of the same substance we may take, and whatever may be the external form—and its varieties number some hundreds—it will, by careful dissection, be resolvable into forms of this shape, and no other regular geometrical form can be extracted from it. Pearl spar, iron spar, and tourmaline, are also resolvable into the same figure; but these are all distinguishable from each other by accurate measurement of the angles, by means of an instrument invented for this purpose, called a *goniometer*.

Other crystals, again, are resolvable into other primitive forms. A cube of *fluor-spar*, for instance, may have its solid corners removed by the edge of a knife; and it will then, if the dissection be continued far enough, be resolved into a regular octohedron (see III). This is likewise true, whatever secondary form of fluor spar we make the subject of experiment. Even in the very hardest gems we find this cleavage. Those who are in the habit of cutting and polishing such stones, have long been aware of this circumstance; and, indeed, cleavage may be stated as a general law of crystallized bodies.

Abbé Haüy was the first to make a real use of cleavage for the dissection of crystals; but the illustrious Bergmann had before shown that the different forms of the same substance are produced by the superposition of planes, sometimes constant, and sometimes variable and decreasing, and of one and the same primitive form; and applied this primary idea to a small number of crystals. He stopped short at this point; but, simple as the sketch was, we see in it the same master-hand that so successfully filled up the outlines of chemistry. Haüy took up the idea, and has obtained the honour of having originated it, and perhaps it became truly his own, from the fertile use he made of the discovery.

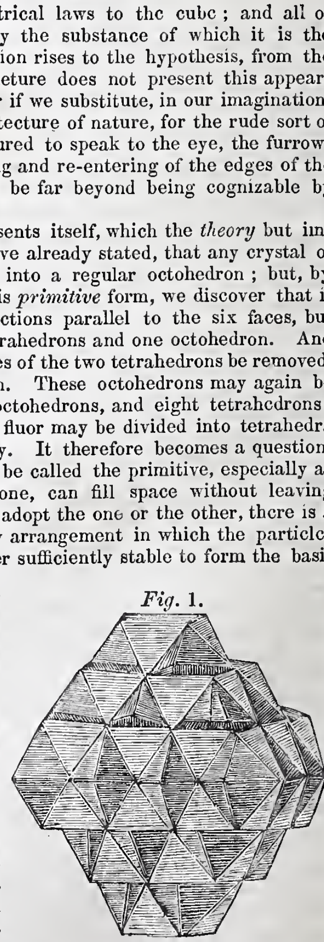
Following out the cleavage of a crystal, we readily find that the first resulting primitive form is not the last term of the mechanical division; for this may always be subdivided, parallel to its different faces, and the form will vanish only when the substance has become too minute for our organs of vision. Where, then, we would ask, does this division terminate?—where lies the last term of these primitive forms? The question requires no answer; for the last term must be the last integrant particle of which the crystal is composed. And if this be admitted, it requires only a single admission farther—one which follows without any violence of good reasoning—and we descend at once upon the conclusion, that the figure of the primitive crystal must be the form of the integrant particles of which it is composed. It was in this way that Haüy, guided by the mechanical division of different crystals, came to his conclusions respecting the forms of the ultimate molecules of crystalline substances. The primitive forms of crystals, as already stated, he reduced to six, but these are again resolvable, by mechanical analysis, into three; 1st, the parallelopiped, the simplest of all solids, having six faces parallel, two and two (see VI.); 2d, the triangular prism, the simplest prism, bounded by five surfaces; 3d, the tetrahedron, the simplest of pyramids, bounded by four surfaces (see I). These are the forms which he assigned to the integrant particles, and by their aggregation externally modified, according to geometrical laws, he conceived all crystallized structures to be determined; and it must be admitted, that, considering the endless diversity of size, proportion, and density, to which the integrant particles of different bodies, though they have the same figure, may still be liable, these few forms may be accounted perfectly sufficient for all the differences in cohesion. It is further held, that since four planes at least are necessary to circumscribe a space, it is evident that the three forms in question, in which the number of faces is successively four, five, and six, have still, in this respect, the greatest possible simplicity. And again, "these integrant particles, when they unite to form the primitive crystals, do not always join together in the same way; sometimes they unite by their faces, and at other times by their edges, leaving considerable vacuities among them. This explains why integrant particles, though they have the same form, may compose primitive crystals of different figures.'

It is not difficult to admit, that "inconceivably small parallelopipeds, of all varieties of angles, may be built up into masses which would have the same relations of sides and angles" as the integrant parallelopipeds themselves. Observation shows, moreover, that the surrounding matter of a primitive form, is an assemblage of laminæ, which, setting out from that form, decrease in extent, often on all sides at once, and sometimes in certain particular ways only, producing all these modifications which are termed secondary forms. This decrement is effected by regular subtractions of one or more rows of integral molecules, and "the theory, in determining the number of these rows, by means of calculation, succeeds in representing all the known results of crystallization, and even anticipates future discoveries;" that is, indicates possible forms of crystals, but which are not yet known. To understand what is meant by this "law of decrements," let us suppose a compound cube, made up of a large number of small cubes, and that layers of cubic particles, decreasing successively by a row parallel to the edges, are placed upon each of the faces, till pyramids rise upon them, terminated by a single particle, the figure will be converted into a dodecahedron, as represented in the accompanying figure. But if the decrement were to take place upon the angles, instead of the edges of the original cube, the figure will manifestly be converted into an octohedron. By decrements, again, of more than one row of particles at a time, and by intermediate and intermixed decrements taking place, according to the laws of symmetry, we can readily see that a vast variety of secondary forms may be constructed, and all of them related by geometrical laws to the cube; and all of them might be assumed by the substance of which it is the primitive form. No objection rises to the hypothesis, from the circumstance, that the structure does not present this appearance in the real crystal; for if we substitute, in our imagination, the infinitely delicate architecture of nature, for the rude sort of masonry which we have figured to speak to the eye, the furrows resulting from the projecting and re-entering of the edges of the superincumbent layers, will be far beyond being cognizable by our senses.



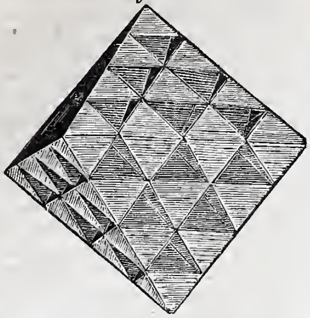
But here a difficulty presents itself, which the *theory* but imperfectly explains.—We have already stated, that any crystal of fluor spar may be resolved into a regular octohedron; but, by further experiment upon this *primitive* form, we discover that it is not only divisible in directions parallel to the six faces, but may be divided into two tetrahedrons and one octohedron. And again, if the four solid angles of the two tetrahedrons be removed, two octohedrons will remain. These octohedrons may again be divided into six smaller octohedrons, and eight tetrahedrons; and thus the whole mass of fluor may be divided into tetrahedra and octohedra, continuously. It therefore becomes a question, which of these forms is to be called the primitive, especially as neither of them, taken alone, can fill space without leaving vacuities; and whether we adopt the one or the other, there is a difficulty in conceiving any arrangement in which the particles may be built up in a manner sufficiently stable to form the basis of a permanent crystal. According to the views of Haüy himself, the particles are to be regarded as tetrahedral, and that the crystal composed is interspersed with octohedral cavities, as represented in fig. 1; but this does not seem a better arrangement than octohedral particles with tetrahedral cavities, as shown in fig. 2. In both of these cases, the mutual contact of the particles is only at their edges; and although it must be admitted that such arrangements may be in equilibrium, they are certainly not consistent with

*Fig.* 1.



our notions of mechanical stability. The phenomena of dissection, moreover, seems opposed to either mode of arrangement; for a cube put together of octohedral particles would necessarily split in directions parallel to its faces, and not to those of the octohedron, which is the fact of experience. It must be noticed, however, that Haüy was himself fully aware of the difficulties of his system,

*Fig.* 2.



regarded as a physical explanation of the phenomena of crystallization, and did not insist upon that part of it which refers to the forms of the ultimate integral molecules, as some of his disciples have very injudiciously done since. In his hands, its use was only to link together a great number of particular and unconnected facts: it was, in short, a mere mathematical hypothesis, by which he was enabled to ascend from the known to the unknown; or as Whewell remarks, "it was like a geometrical diagram: it had its important uses in the advancement of science, but it had no physical meaning."

To obviate the incongruities which beset Haüy's system as a physical explanation of crystallization, Dr Wollaston brought forward another hypothesis, in which he considers the primitive particles as spheres, which, by mutual attraction, assume that arrangement which brings them as near to each other as possible. The relative position of any number of equal balls in the same plane, when gently pressed together, every three forming an equal-sided triangle, is familiar to every one. Fig. 1, is a perspective view of such an arrangement. It is further evident, that if balls so placed were cemented together, and the stratum thus formed were afterwards broken, the straight lines in which they would be disposed to separate would form angles of 60 degrees with each other. If a single ball were placed anywhere at rest upon this stratum, it is evident that it would be in contact with three of the lower balls (fig. 2); and that the lines joining the centres of the four balls so in contact, or the planes touching their surfaces, would include a regular tetrahedron having all its sides equal triangles. A square of four balls, again, with a single ball resting upon the centre of each surface, would form an octohedron (fig. 3); and upon applying two other balls at opposite sides of the octohedron, the group will represent the acute rhomboid (Fig. 4). Other forms may be readily constructed by due application of spheres to each other; but it is needless to pursue any other modifications of the same form, which must result from a series of decrements according to laws which are well exemplified in the piles of shot disposed in an arsenal. Thus, then, the simplest arrangement of the simplest solid which can be imagined removes the difficulty with regard to fluor-spar, and, indeed, fulfils nearly all the functions of the molecular forms assumed by Haüy, and where the perfect sphere fails to account for all the phenomena: oblate and oblong spheroids are found to answer the required conditions.*

*Fig.* 1.

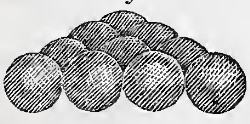


*Fig.* 2.

*Fig.* 3.

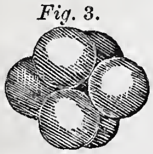
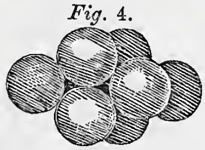
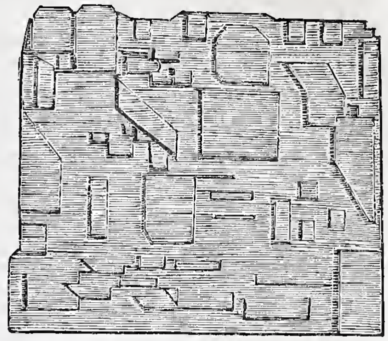


*Fig.* 4.



Some of the researches of Professor Daniel are supposed to afford some confirmations of Dr Wollaston's hypothesis. He immersed, for instance, an amorphous piece of alum in water, and left it quietly to dissolve: at first the water acted upon it in all directions alike; but, as the solution approached its point of saturation; that is, when the force of adhesion between the particles of the water and the salt became nearly balanced by the homogeneous cohesion of the saline particles, the latter yielded only in the lines of least resistance, determined by the regular structure of crystalline arrangement, and the surface became embossed with the forms of octohedrons and sections of octohedrons, and an immense variety of geometrical figures stamped upon it, as it were, or carved upon its substance, as represented in the figure. Other salts yield other figures, and, more by complicated chemical action, as of acids on carbonate of lime, on metals, &c., analogous results are obtained. A mass of nickel, for instance, soon becomes covered with tetrahedral figures of great relief and beauty, by the action of nitric acid; and gold, when carefully cast and cooled, by the action of *aqua regia*. The beautiful forms of the *Moirée metallique*, which have ceased to be admired for the very cheapness of the operation, are procured by a process strictly analogous.



From these cases of the dissection of a crystal by solution, it is evident that no theory of crystallization can be admitted which is not founded upon such a disposition of the constituent particles, as may furnish all the modifications of form developed, by mere abstraction of certain others from the congeries, and without altering the original relative position of those which remain; and these conditions may be fulfilled by such an arrangement of spherical particles, as would arise from the combination of an indefinite number of spheres or spheroids, endowed with mutual attraction; and no other geometrical solids seem adequate to the purpose. It may further be *conjectured*, that the exterior shape of every crystal is determined by the nucleus first formed by a certain definite number of particles, which, by the power of mutual attraction, overcome the resistance of the medium in which they were suspended, or from which they were separated: this number may vary with the solvent or other contingent circumstances.

"The light which the theory of definite proportions has thrown upon chemistry; the mechanical views by which the atomic philosophy accounts for fixed proportions; the use which has been made of these views to represent bodies composed of a determinate number of atoms, engaged M. Mitscherlich to examine the following problems:—

Different elements being combined with the same number of atoms of one element, or of several different elements, have they the same crystalline *form?*

Is the identity of the crystalline form determined only by the *number* of atoms? Is this form independent of the chemical nature of the elements?

"The trials which he has made appear to him to demonstrate, that certain different elements, combined with the same number of one or of several elements, affect the same crystalline form; and that chemical elements in general may in this respect be classed in groups. He gives the epithet *isomorphous* to those elements which belong to the same group, in order to express this quality of the elements by a technical term. Thus, every arseniate, he says, has a phosphate which corresponds to it, composed according to the same proportions, combined with the same atoms of water of crystallization, and which at the same time has the same physical qualities. In a word, the two series of salts with the phosphorous and phosphoric, arsenious and arsenic acids, differ in no respect, except that the radical of the acid of one series is phosphorus, and of the other is arsenic.

"The conclusion at which he arrives, is: the same number of atoms, combined in the same manner, produces the same crystalline form; and the same crystalline form is independent of the chemical nature of the atoms, being determined only by their number and relative position."†

* Philos. Trans, 1813.

† Ann. de Chem. et Phys. xix. 350.

There is, however, another phenomenon in the crystallization of some substances, which is of great interest in the present state of chemical physics, and which has not been explained by any hypotheses that have yet been framed. The phenomenon referred to is the capability of certain bodies to assume two positively different forms, thus connecting themselves with two distinct and different systems of crystallization, and cannot be derived from one another. These are called *dimorphous* (two-formed) bodies, and they are found both among simple and compound substances. The earliest case of this sort observed was that of carbonate of lime, in the two incompatible forms of calc spar and arragonite. We have already referred to the rhombohedral structure of the former, but in the case of arragonite, similar dissection shows the primitive form to be a *right rhombic prism* (of 116° 16′). Sulphur, as it occurs native, and as it is deposited from solution of the liquid called bisulphuret of carbon, forms crystals which are octohedrons with rhombic bases; but when it is melted and allowed to cool slowly, it crystallizes in *oblique rhombic prisms:* these two forms are also geometrically incompatible. Carbon occurs in nature in two states: as diamond, crystallized in regular *octohedrons;* and as graphite, which crystallizes in *rhombohedrons,* or six-sided plates; also incompatible forms. Brown iron spar is a carbonate of iron which crystallizes in rhomboids; the mineral called junckerite is the same substance crystallized in an incompatible prismatic form. Iron pyrites (bisulphuret of iron) are found abundantly in cubes, and also with an incompatible prismatic structure. The minerals called garnet and idocrase are identical in chemical composition; yet the garnet is found in *regular dodecahedrons,* and idocrase in *square prisms.* Many other similar instances of dimorphism have already been detected, though the subject has only of late excited the attention of scientific men.

It is perhaps not to be expected, that any hypothesis can ever be framed to embrace all the circumstances of dimorphism: the circumstances necessary to be embraced appear to be as numerous as the cases observed. For instance, nitre, by being crystallized in large and in very small quantities, takes incompatible forms; and sulphate of nickel takes one form of crystal when evaporated at common temperatures, and another when the solution is exposed to the sun's rays or when evaporated by heat. Lyell mentions it as a remarkable geological fact, that augite and hornblende are very rarely associated together in the same rock; and when this happens, as in the lavas of modern date, the hornblende occurs in the mass of the rock where crystallization may have taken place more slowly, while the augite merely lines cavities where the crystals may have been produced rapidly. It is also remarked, that in the crystalline slags of furnaces, augitic forms were frequent, the hornblende entirely absent: hence it is conjectured, that hornblende may be the result of slow, and augite of rapid, cooling. This view is confirmed by the fact, that Mitscherlich and Berthier were able to make augite artificially, but could never succeed in forming hornblende. And more lately, Gustavus Rose fused a mass of hornblende in a porcelain furnace, and found that it did not, when cooling, assume its previous shape, but invariably took that of augite: from these facts we may infer that the same substance may assume the crystalline forms of hornblende or augite indifferently, according to the more or less rapid cooling of the melted mass.

## MATHEMATICS.

### CHAPTER II.

#### FUNDAMENTAL OPERATIONS OF ARITHMETIC.

All processes in arithmetic consist in the increase or diminution of numbers, and might consequently all be performed with pebbles, provided unlimited time was allowed to perform them. But time is valuable, and therefore shorter and less complex ways of counting have been invented, whereby, in many cases, the labour of years is reduced to the work of a few minutes, and by which we are, in fact, enabled to make calculations with facility, which no human patience would have dared to undertake. The four great methods we employ are denominated, addition, subtraction, multiplication, and division; but the two last, as we shall afterwards see, are only convenient modes of doing several of the first and second at once. To give a general notion of these methods and their connexions with one another, we shall consider, in the first place, their applications to the management of numbers expressed by single figures.

1. *Addition.* This is the name which we give to the operation by which several assemblages are collected into one whole, called the *sum.* It is founded on the obvious principle, that "a whole is equal to all its parts taken together." Thus nine halfpence may be disposed of in three groups, the 1st containing two, the 2d four, and the 3d three halfpence; and when we have collected together the halfpence in these groups into one assemblage, and written the numerical sign, we have done a case of addition. To add numbers together means, therefore, nothing more than to find out a single number, the name of which shall truly express the value of the several groups taken collectively.

Every number, indeed, which consists of several units, may be regarded as a *sum* formed by the successive addition of these units. Thus, 2 is the sum of 1 and 1 more, 3 is the sum of 2 and 1 more, and so on; and however high a number may be, it conveys simply the meaning of a sum of *ones.*

2. To render the language of arithmetic shorter, we use a few arbitrary signs, to denote the operations which are to be performed upon the numbers with which we are operating. The sign by which we express that two numbers are to be added together is St George's cross, written $+$ and usually named *plus,* the Latin word for *more.* Thus, instead of writing, "*add* 2 *and* 4 *and* 3 *together,*" we write $2+4+3$, which is read, 2 *plus* 4 *plus* 3, and this is equally intelligible when the meaning of the sign is known, and it has the advantage of being more concise.

From what has gone before, we know that the expression $2+4+3$ is truly expressed by 9; but in order to indicate this equivalence of value in a concise manner, we use another sign composed of two parallel lines, thus $=$. This is read *equals,* an is called the sign of equality, because it is only used between two numbers, or collections of numbers, the values of which are exactly the same. Thus, to indicate that the value of $2+4+3$ is 9, we write $2+4+3=9$. This is called an equation, and is read as a whole 2 *plus* 4 *plus* 3 *equals* 9. It is plain that we may make as many such equations as we please, and the following table of them should be made three or four times over, and extended by the learner himself, to all numbers less than 10. This will familiarize him with the signs, and the addition of the simple numbers, of which large numbers are made up.

| | |
|---|---|
| $2+2=4$ | $5+7=6+6=8+4=12$ |
| $2+4=3+3=6$ | $4+9=5+8=6+7=13$ |
| $2+6=3+5=8$ | $5+9=6+8=7+7=14$ |
| $3+7=4+6=10$ | $6+9=7+8=15$ |
| $3+8=7+4=11$ | $7+9=8+8=16$ |
| $3+9=4+8=12$ | $9+8=17$ $\quad 9+9=18$ |

3. *Multiplication.* It frequently happens, that the numbers to be added are all equal to each other, as for instance,

$$2+2+2+2+2=10$$

This species of addition takes the name of *multiplication,* and is expressed 2 *repeated* 5 *times,* or more commonly 5 *multiplied by* 2. The sign by which it is denoted, is St Andrew's cross, written $\times$ and read *multiplied by* or more shortly *into.* Thus 5 *multiplied by* 2, or 2 *repeated* 5 *times,* is expressed symbolically, by $5\times 2$ which is the same thing as $2+2+2+2+2$ and is much shorter. Multiplication then is to be considered, simply, a concise method of finding the sum of several numbers when they are all equal to one another; and by its rules we are often able to perform with a few figures, operations which would otherwise require long and tedious reckoning.

4. *Subtraction.* After we have learned to compose a number by the addition of several others, the first question which presents itself regarding two unequal quantities is, how much the one exceeds the other; that is, how many units must be added to a less number to make it equal to a greater, or how many must be taken away from a greater number to make it equal to a less one. To take a case: suppose we have the numbers 9 and 5 given, and we wish to find out their *difference;* two methods at once present themselves: we may take away unit after unit, from 9, until 5 only are left, and the number of units so taken away,

will of course show the excess of 9 over 5; or we may proceed by an opposite process with 5, and find by successive additions of 1, how much it falls short of 9: both processes show that the difference between the numbers is 4, and the proof is, that $5+4=9$. But this suggests that the question may be viewed more simply: for if the sum of 5 and 4 be 9, then is it obvious that we may regard 9 as composed of these two parts, and as one of them was given the whole operation comes to the taking away of the 5 from the 9. This for brevity is indicated by placing the sign — between the numbers, writing the greater number on the left, and the lesser on the right, thus $9-5$. The sign is read *minus*, the Latin word for *less*, meaning that the first number is to be *lessened* by the second: $9-5$ will then be read 9 *minus* 5, or 9 *lessened* by 5. When this operation is completed, we call the number which is left the *remainder;* but when we remark the inequality of 9 and 5, without fixing attention on the order of their magnitude, we say their *difference* is 4. We may use these terms synonymously, however, without any risk of confusion: both denote the answer to a question of subtraction, and verbal nicety is the only reason why at times we should use the one in preference to the other.

After acquainting ourselves with the addition of numbers up to $9+9$, the cases of subtraction within the same limits cannot present much difficulty: we however present the following equations, for the sake of affording exercise in the use of the sign: their number may be extended at pleasure until expertness is attained.

$$5-3=2 \qquad 8-5=3 \qquad 6-2-1=3$$
$$7-3=4 \qquad 9-4=5 \qquad 9-4-3=2$$

From what has been already said, it is obvious that in all cases the answer may be proved to be correct, or otherwise, by adding together the remainder and number subtracted (called usually the *subtrahend*), if the same be equal to the number from which the subtraction was made, (called the *minuend*,) the result is correct.

$$\text{Thus, } 11-5=6 \text{ because } 5+6=11$$
$$15-8=7 \qquad 8+7=15$$

5. We shall have occasion for the following proposition, when we come to deal with cases of subtraction which involve high numbers, and may, therefore, in the meantime, satisfy ourselves of its truth. It is this: *The difference between two numbers is not altered by augmenting or diminishing both by the same quantity;* that is, by adding a number to the first, if you add the same number to the second; or by subtracting a number from the first, if you subtract the same number from the second.

$$\text{Thus, } 3-1=5-3=7-5=9-7=11-9=2$$
$$11-9=9-7=7-5=5-3=3-1=2$$

Many other cases should be extended in the same way as these two, and in fact, the proposition *should not* be passed over until its truth has been perfectly comprehended. The following praxis on the signs may also be useful, as models by which to construct other cases.

$$7+3-2=8 \qquad 9-5+2=6 \qquad 8+5-4=9$$
$$7-5-1+2+5=8 \qquad 9+3-6+8-7+1=8$$

6. *Division.* This is nothing more than a short way of performing many subtractions of the same number, just as multiplication was shown to be a ready method of performing many additions of the same number. For instance, to divide 10 by 2, is to find out how often 2 may be taken from 10—The answer is, 5 times. The sign by which we *frequently* (not always) denote division, is $\div$; so that $10\div 2$ is the short way of putting the question—*How often is it possible to subtract* 2 *from* 10*?* But such an expression is usually read, 10 *divided by* 2, or more shortly still, 10 *by* 2. From this it appears, that as addition and subtraction are inverse operations—the one finding the sum of numbers, and the other their difference—and as multiplication is nothing more than a compendious mode of performing that species of addition wherein numbers to be added are the same, division may be strictly regarded as the inverse of multiplication—a concise mode of subtracting, when the numbers to be subtracted are all the same, or when it is required to find how often the *same* number can be subtracted.

With these remarks on the nature and relations of the fundamental operations on numbers, we shall now turn our attention to the rules of each, as applied to magnitudes of all dimensions, taking them in the order at first announced—Addition, Subtraction, Multiplication, and Division. In this chapter we shall consider the first two, leaving Multiplication and Division for subsequent discussion. At this point, also, we will presume that the learner is now able to find the sum and difference of all numbers less than 10, with facility; without this he will make little progress in high numbers. We also advise him to make himself familiar with the meaning of the signs + and —; a thorough acquaintance with the use of these, is of more importance to his successful prosecution of mathematical studies, than we can possibly, in the meantime, make him comprehend. It is true, indeed, that he might acquire a sufficient knowledge of arithmetic to be able to sum up columns of pounds, shillings, and pence, without troubling himself about either + or —, and assuredly, had we contemplated no higher ultimatum, we would not have even intimated their existence. But we would not be misunderstood—we write not for those whose ambition has such a limit; we write for those who are willing to acquire a knowledge of the principles, as well as the practice, of arithmetic, and who are looking forward to make that knowledge a key to further attainments.

### ADDITION.

1°. Suppose it required to find the sum of the two numbers, 38 and 45. Here $38=3$ tens$+8$ units, and $45=4$ tens$+5$ units. Now it is evident, that 38 and 45 will be added together, when we have added together all the parts of which these numbers are composed; but they are composed of 3 tens$+4$ tens $=7$ tens, and 8 units$+5$ units$=13$ units; the sum is therefore 7 tens and 13 units. But 13 units$=1$ ten$+3$ units; and hence, 7 tens$+13$ units$=8$ tens$+3$ units, that is, 83. The same may be done more concisely, by using the cipher instead of the word *ten.*

$$\begin{aligned}\text{Thus, } 38+45 &= \overline{30+8}+\overline{40+5}\\ \ldots &= 30+40+8+5\\ \ldots &= 70+13=70+10+3\\ \ldots &= 83\end{aligned}$$

From this example it appears that the tens and the units of the proposed numbers must be collected together separately.

2°. Let it be required to add together 3689 and 1634.

Here, 3689 = 3 thous. 6 hund. 8 tens and 9 units.
1634 = 1 thous. 6 hund. 3 tens and 4 units.

If, now, to each part of the first number we add each part of the second which is under it, we will evidently have added together, as in the last case, the given numbers, 3689 and 1634; the sum required is therefore

4 thous. 12 hund. 11 tens and 13 units

But, 13 units = 1 ten and 3 units
11 tens = 1 hund. & 1 ten
12 hund. = 1 thous. & 2 hund.
4 thous. = 4 thous.

and adding the parts that are here again, under each other, we get

3689 + 1634 = 5 thous. 3 hund. 2 tens and 3 units = 5323.

The same process, using the signs and ciphers, is as follows:—

$$\begin{aligned}3689 &= 3000+600+80+9\\ 1634 &= 1000+600+30+4\\ \hline 3689+1634 &= 4000+1200+110+13\\ \text{But, } 13 &= 10+3\\ 110 &= 100+10\\ 1200 &= 1000+200\\ 4000 &= 4000 \qquad \text{Therefore}\\ 3689+1634 &= 5000+300+20+3=5323\end{aligned}$$

From this we learn, generally, that all the parts of the given numbers are to be added together separately; and further, that, the significant figure on the left hand, when a denomination of the result has two (or more) such, is always to be added or *carried* to the next higher place; as every place of the final result, from the nature of our numeration scale, (chap. i. sect. 7,) can only contain one figure; thus, the 1 ten of the 13 units ($=1$ ten $+3$ units,) is to be added to the 11 tens, making 12 tens$=1$ hund.$+2$ tens; and the 1 hund. is to be added to the 12 hund., making 13 hund.$=1$ thous.$+3$ hund.; and finally, the 1 thous. is to be added to the 4 thous., making 5 thous.; making, as already stated,

5 thous.$+3$ hund.$+2$ tens$+3$ units; that is, 5323.

The following equations may be proved in the same way :—

$24+37=61 \qquad 2834+2799=5633$
$49+78=127 \qquad 5678+4867=10545$

The process being now thoroughly studied, we may translate the successive operations into the following rule :—

I. *Write the numbers which are to be added together, under one another,* (for convenience,) *so that the figures which express the units shall all be in one column; those which express tens, all in another column; those which express hundreds, in a third column; and so on.*

II. *Add together all the figures in the column of units, and if the sum does not exceed* 9, *write it beneath; but if it exceeds* 9, *separate it into units and tens, and write down the units under the unit column, and keep the number of tens in memory,* (or write down their number under the column of tens).

III. *Regard the tens obtained by the addition of the unit column, as units of the column of tens, and find the sum of that column with this addition;—if, as in* II., *the number does not exceed* 9, *write it beneath the column, but if it exceeds* 9, *separate it into units of tens, and tens of tens, that is, into tens and hundreds,* (which may be regarded as units and tens, exactly as before); *then write the number of tens beneath the column of tens, and reserve the hundreds to be added to the next column, that is, the column of hundreds.*

IV. *Proceed exactly in the same way through every column, setting down always the right hand figure of the sum obtained,* and carrying *all the figures on the left of it to the next higher column, till arriving at the last column, under which write down the whole sum found by adding it.*

As an example of this rule, let it be required to find the sum of

$$7658+9684+786+196+3060+5196.$$

We shall here write down the numbers on the left, as the rule requires, and on the right, in detail, so that the identity of the methods may be as obvious as possible.

| By rule. | | In detail. |
|---|---|---|
| 7658 | = | 7 thous. 6 hund. 5 tens 8 units |
| 9684 | | 9 thous. 6 hund. 8 tens 4 units |
| 786 | | 7 hund. 8 tens 6 units |
| 196 | | 1 hund. 9 tens 6 units |
| 3060 | | 3 thous. 0 hund. 6 tens 0 units |
| 5196 | | 5 thous. 1 hund. 9 tens 6 units |
| Sum, 26580 | = | 26 thous. 5 hund. 8 tens 0 units |

The calculation is gone through as follows :—

Units $=6+0+6+6+4+8=30$ units $=3$ tens $+0$ units
Write down the 0, and carry the 3.

Tens $=3+9+6+9+8+8+5=48$ tens $=4$ hund. $+8$ tens
Write down the 8, and carry the 4.

Hund. $=4+1+0+1+7+6+6=25$ hund. $=2$ thous. $+5$ hund.
Write down the 5, and carry the 2.

Thous. $=2+5+3+9+7=26$ thous.; which write down.

In practice it is, of course, unnecessary to attend to ciphers, when they stand in the columns. We have here written them in the work, merely to avoid any difficulty which might possibly arise by their omission. There are several methods of proving the accuracy of the result; but the simplest, and therefore the best, is to make the addition twice, beginning at the bottom of the columns, and adding upwards the first time; and at the top, and adding downwards the next: if the sum is the same in both cases, it may be considered correct.

The student may now examine whether the following additions be correctly made :—

$$5783+4318+5987+8527=24615$$
$$77756+3388+9763+90257=181164$$
$$10376786+789632+589+73=11167080$$
$$5784200+200003+549830+14378539=20912572$$

It will afford some further exercise to prove that the sum of the numbers, in every row of the following table, whether reckoned upright, or from right to left, or from corner to corner, is 24156.*

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 2016 | 4212 | 1656 | 3852 | 1296 | 3492 | 936 | 3132 | 576 | 2772 | 216 |
| 252 | 2052 | 4248 | 1692 | 3888 | 1332 | 3528 | 972 | 3168 | 612 | 2412 |
| 2448 | 288 | 2088 | 4284 | 1728 | 3924 | 1368 | 3564 | 1008 | 2808 | 648 |
| 684 | 2484 | 324 | 2124 | 4320 | 1764 | 3960 | 1404 | 3204 | 1044 | 2844 |
| 2880 | 720 | 2520 | 360 | 2160 | 4356 | 1800 | 3600 | 1440 | 3240 | 1080 |
| 1116 | 2916 | 756 | 2556 | 396 | 2196 | 3996 | 1836 | 3636 | 1476 | 3276 |
| 3312 | 1152 | 2952 | 792 | 2592 | 36 | 2232 | 4032 | 1872 | 3672 | 1512 |
| 1548 | 3348 | 1188 | 2988 | 432 | 2628 | 72 | 2268 | 4068 | 1908 | 3708 |
| 3744 | 1584 | 3384 | 828 | 3024 | 468 | 2664 | 108 | 2304 | 4104 | 1944 |
| 1980 | 3780 | 1224 | 3420 | 864 | 3060 | 504 | 2700 | 144 | 2340 | 4140 |
| 4176 | 1620 | 3816 | 1260 | 3456 | 900 | 3096 | 540 | 2736 | 180 | 2376 |

It is sometimes necessary to add very long columns of figures amidst interruptions, and considerable annoyance is often experienced by forgetting the carriage figure, and in consequence having to begin the addition anew. Under these circumstances, it is advisable to begin the addition at the left, and *write* always the right hand figure of each individual sum under its respective column, and the carriage figure a place to the left. This will give the sum of the columns in two lines, which, when added together, will be the sum sought. The example annexed will make this plain, if the principle of addition itself be rightly understood. The same artifice might be adopted, and still begin at the units column, but on trial it will be found less convenient.

| |
|---:|
| 536789 |
| 436121 |
| 317600 |
| 134674 |
| 236789 |
| 234251 |
| 321446 |
| 2084340 |
| 13333 |
| 2217670 |

SUBTRACTION.

We have already stated it as a principle to be borne in mind, that the difference between two numbers is not altered by increasing or diminishing both numbers by the same number. For instance, the numerical difference of two armies will remain the same although each should be reinforced by 1000 men, and it will not be affected by withdrawing 1000 from each. We may also lay it down as an axiom, that the difference between two numbers is made up of the sum of the differences between the parts of which those numbers are composed.

Thus, 9 exceeds 7 by 2,
and 4 exceeds 3 by 1,
and 8 exceeds 5 by 3.

Therefore $9+4+8=21$ exceeds $7+3+5=15$ by $2+1+3=6$.

If these principles be understood, we shall have no difficulty with respect to subtraction. To take an example :—

1. Let it be required to subtract 6835 from 8976.

Here $8976=8$ thous. 9 hund. 7 tens and 6 units.
$6835=6$ thous. 8 hund. 3 tens and 5 units.

Now 6 *units* exceed 5 *units* by 1 *unit.*
7 *tens* exceed 3 *tens* by 4 *tens.*
9 *hund.* exceed 8 *hund.* by 1 *hund.*
8 *thous.* exceed 6 *thous.* by 2 *thous.*

Therefore 8 thous. 9 hund. 7 tens and 6 units $=8976$
exceed 6 thous. 8 hund. 3 tens and 5 units $=6835$
by 2 thous. 1 hund. 4 tens and 1 unit $=2141$

that is, 8976 exceeds 6835 by 2141,

or, 6835 subtracted from 8976 leaves 2141,

or, $8976-6835=2141$ as required.

This question, then, is answered by applying only the second of the foregoing principles: we shall now take a case where it will be necessary to apply both.

2. Subtract 19786 from 31814, that is, find $31814-19786$.

* Tables of this sort are called magic squares. A number of them may be seen in Hutton's Mathematical Recreations and Mathematical Dictionary. That inserted here is among the most extensive we have seen; we do not know to whom we are indebted for its construction. It is taken from De Morgan's Arithmetic, but we have too high an opinion of that author to suppose that he wasted time in making it.

These numbers written in detail as before, are

3 ten-thous. 1 thous. 8 hund. 1 ten and 4 units
1 ten-thous. 9 thous. 7 hund. 8 tens and 6 units.

Here we at once perceive that we cannot proceed as in the ast example, for 6 units are more than 4 units, and 8 tens than 1 ten, and further on we find 9 thous. standing beneath 1 thous. But recollecting that we may add the same number to *both* of the given numbers, without altering their difference, (and the difference is that which we are in quest of,) we proceed to apply the principle in this manner: add ten to the 4 units of the upper line, making 14 units, and one to the 8 tens of the under lines, making 9 tens; so that the numbers will now read

3 ten-thous. 1 thous. 8 hund. 1 ten and 14 *units*,
1 ten-thous. 9 thous. 7 hund. 9 *tens* and 6 units.

Again, add 1 hund. $=10$ tens to the 1 ten in the upper line, making 11 tens, and 1 hund. to the 7 hund. of the under line, making 8 hund. so that now the numbers will read

3 ten-thous. 1 thous. 8 hund. 11 *tens* and 14 *units*,
1 ten-thous. 9 thous. 8 *hund.* 9 *tens* and 6 units.

Lastly, add 1 ten-thous. $=10$ thous. to the 1 thous. of the upper line, making 11 thous. and 1 ten-thous. to the 1 ten-thous. of the under line, making 2 ten-thous., so that the number will read

3 ten-thous. 11 *thous.* 8 hund. 11 *tens* and 14 *units*,
2 *ten-thous.* 9 thous. 8 *hund.* 9 *tens* and 6 units.

Now, these numbers are not the same as those given; but we know that their difference must be the same since we have made exactly the same additions to each; and by subtracting the one from the other, as we did in the first example, we get as the difference sought

1 ten-thous. 2 thous. 0 hund. 2 tens and 8 units,

that is 12028. Therefore $31814-19786=12028$, and the proof is, that $19786+12028=31814$.*

We may now imbody these processes in a rule, as follows:—

I. *Write the number which is to be subtracted,* (which is of course always the lesser of the two and is called the SUBTRAHEND,) *under the other,* (which is called the MINUEND,) *so that its units may fall under the units of the other, the tens under the tens, and so on.*

II. *Subtract each figure of the lower line from that above it, if that can be done. When that cannot be done, add* 10 *to the upper figure, and then subtract the lower figure, but when that is done, recollect to add* 1 *to the next figure in the lower line before subtracting it from its corresponding figure in the upper line.*

EXAMPLE.—Find $867543267-164567345=?$

Arrange the numbers as directed in I. of the rule. Here $7-5=2$; $6-4=2$; $2-3$ is impossible, but $12-3=9$, and carry 1; then $3-(1+7)=3-8$ is again impossible, but $13-8=5$ and carry 1; $4-(1+6)=4-7$ is also impossible, but $14-7=7$ and carry 1; $5-(1+5)=5-6$ is also impossible, but $15-6=9$ and carry 1; $7-(1+4)=2$; $6-6=0$; and $8-1=7$.

| | |
|---|---|
| Minuend | $=867543267$ |
| Subtrahend | $=164567345$ |
| Remainder | $=702975922$ |

The work is readily proved by adding together the remainder and subtrahend, the sum of course should be the minuend.

The following instances may now be verified for the sake of exercise:—

| | |
|---|---|
| 33758317658 | 8756789675436 |
| 21869433245 | 7900976080978 |
| 11888884413 | 855813594458 |

Should there not be as many figures in the under line as there are in the upper one, the deficiency may be *actually* made up with ciphers; but it saves trouble to proceed without writing them, simply bearing in mind that the line may be so extended.

This direction is founded on the evident fact, that a number is not altered in value by placing ciphers on the left of it. Thus, 321 is the same as 00321, for it means

3 hundreds, 2 tens, and 1 unit,

and 00321 means in reality nothing more; for

0 ten-thousands, 0 thousands, 3 hundred, 2 tens, and 1 unit,

merely differs in saying that the number contains no tens of thousands, and no thousands. It would be very different, however, were the ciphers placed on the right; for then the 3 would become tens of thousands, the 2 would be thousands, and the 1 would mean a hundred, and the ciphers would denote that there were no tens or units. The following are instances in which these remarks are applicable:—

| | | |
|---|---|---|
| 8360000 | 1842007 | 30000680 |
| 6756 | 90009 | 9091 |
| 8353244 | 1751998 | 29991589 |

When two or more numbers are given to be subtracted from two or more other numbers, it is *generally* best to add together all those belonging to the minuend, and then all those belonging to the subtrahend, and to take the sum of the one set from the sum of the other; thus,—

From $675+70+1211+673$, subtract $31+910+76+106+78$.

Here, $675+70+1211+673=2629$; and $31+910+76+106+78=1201$;

Then, $2629-1201=1428$.

Find the difference between $6173+95+78$, and $867+712+81$. *Answer*, 4686.

What is $2572-183+17856-1273+534$? *Answer*, 19506.

There is an expeditious and elegant mode of subtracting numbers by means of what is called the *arithmetical complement.* It is not taken notice of in our elementary treatises on arithmetic, because it requires the learner to know something about the principle before he can practise it with success, and this is reckoned superfluous in the *art of ciphering.* We shall try to make it plain.

Let it be required to find $1000-732$. The answer, by the common rule, is 268; but we shall obtain exactly the same result by subtracting the units from 10, and the other figures successively from 9.†

Thus, $10-2=8$; $9-3=6$; and $9-7=2$.

We may therefore state it as a rule, that to *subtract a number from* 1, *followed by as many ciphers as the number has figures, the figure in the unit's place must be subtracted from* 10, *and the others from* 9:

Thus, $1000000-708367=291633$.

This process, which is so easy that it scarcely deserves to be counted an operation, is made use of for our purpose in the following manner:—

Let the difference $3487-259$ be required.

It is here evident that by decomposing 3487 into $2487+1000$, the difference between it and 259 is not altered, and we shall have

$2487+1000-259$; but $1000-259=741$;

Therefore, $2487+1000-259=2487+741=3228$.

Thus, instead of subtracting 259, we have, in fact, added 741 and all cases of subtraction may be reduced to cases of addition in the same way. The following subtractions may be made by this mode, and then we will show how the rule may be somewhat shortened.

$1660-786=874$ $\qquad$ $4686-996=3690$.

All that is necessary to the shortening of the process, is the admission of this principle: *the difference between two numbers is not altered by adding a number to it, if at the same time we subtract the same number from it.* Let this number always be 1, followed by as many ciphers as the number to be subtracted has figures

Thus, suppose it is required to find the difference $9846-635$.

* We might have considered the case differently, and have arrived at the same result without these successive additions; thus,

31814 may be written 2 ten-thous. 11 thous. 7 hund. 10 tens and 14 units.
19786 as before 1 ten-thous. 9 thous. 7 hund. 8 tens and 6 units.

And taking the one from the other, we get as before,

1 ten thous. 2 thous. 0 hund. 2 tens and 8 units.

The method shown in the text, however, leads more directly to the common rule, which we believe to be preferable to that founded on the method shown here. If either of the methods, however, be understood, there will be no difficulty in understanding the other.

† This is the principle noticed in the note preceding; for $1000=9$ hundreds, 9 tens, and 10 units.

Here, by adding 1000 and subtracting 1000, we get

$$9846+1000-635-1000\,;$$

But, by performing the operation $1000-635$, we get

$$9846+365-1000.$$

Now, all that remains to be done is, to add 365 to 9846, and to subtract 1 from the thousands of the result; but we might put the 365 in place of the ciphers in 1000, provided we put some mark upon the 1 to show, that while the other figures are to be added, that this one is to be subtracted. This is done by placing a dash, answering to the sign of subtraction, over the 1, making it $\bar{1}$, and making $365-1000$ into $\bar{1}365$. This artifice will convert the above expression into

$$9846+\bar{1}365=9211\,;$$

a calculation which is otherwise shown in the margin.

$$\begin{array}{r} 9846 \\ \bar{1}365 \\ \hline 9211 \end{array}$$

The quantity $\bar{1}365$, is what is called the *arithmetical complement* of 635; and generally to find the arithmetical complement of any number, we must subtract the units' figure from 10, the others from 9, and place $\bar{1}$ on the left of the result. It will also be observed, that *this complement, added to the number, gives* 0 *for the sum.* Thus $635+\bar{1}365=0000=0$. Farther, *every case, where it is required to subtract a number we may add its arithmetical complement.*

As we can readily perform such subtractions as $1000-635$ mentally, in fact, as quickly as we can write the figures, the arithmetical complement furnishes us with a very neat and expeditious way of taking the balance of a successive set of additions and subtractions. For instance,—

$$32731+5729-371-4834,$$

takes the form shown in the margin; the complement of 371 being $\bar{1}629$, and that of 4834 being $\bar{1}5166$; the $\bar{1}$'s in the columns must of course be subtracted as before shown.

$$\begin{array}{r} 32731 \\ 5729 \\ \bar{1}629 \\ \bar{1}5166 \\ \hline 33255 \end{array}$$

Presuming that the preceding principles are well understood, we may now show how sufficient exercise upon them may be obtained, without putting ourselves to the needless trouble of writing such columns of "questions for exercise," as we usually find in books. Let the *industrious* student take a series of numbers, each containing one figure more than the preceding one; say 271, 3567, 46891, 506798, 9763897, and 85438796; and let him subtract each preceding number from that which follows it; thus—

$$\begin{array}{r} 3567 \\ 271 \\ \hline 3296 \end{array} \qquad \begin{array}{r} 46891 \\ 3567 \\ \hline 43324 \end{array} \qquad \begin{array}{r} 506798 \\ 46891 \\ \hline 459907 \end{array} \qquad \begin{array}{r} 9763897 \\ 506798 \\ \hline 9257099 \end{array} \qquad \begin{array}{r} 85438796 \\ 9763897 \\ \hline 75674899 \end{array}$$

Let him then add all his results together, with the least number chosen, and, if his work be correct, the final result will be the greatest number. The completion of the operation is shown beneath.—

$$\begin{array}{rr} \text{Differences} = & \left\{ \begin{array}{r} 75674899 \\ 9257099 \\ 459907 \\ 43324 \\ 3296 \end{array} \right. \\ \text{Least number} = & 271 \\ \hline \text{Greatest number} = & 85438796 \end{array}$$

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We hope that the student, who has here approached the subject for the first time, has found the preceding chapter rather difficult; if he has found it very easy, we advise him to examine it again, for we very much suspect that he has not thoroughly understood it. We might indeed state it as an axiom, that those students who find the greatest number of difficulties in learning mathematics, make the best mathematicians; and conversely, those who find the study exceedingly easy, rarely arrive at any degree of proficiency. The reason is obvious: the one class are *thinkers,* and the other *believers;* the former must see that all is fairly demonstrated, the latter care not for the demonstration of anything.

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# ANATOMY AND PHYSIOLOGY.

## CHAPTER II.

### THE SKIN AND PERSPIRATION.

The skin is composed of four coats, the external, two middle, and the internal. 1st. The external coat is a thin cuticle, or scarf skin, endued with little sensibility, intended for a covering to the body, to protect it from outward irritation, and shield it from immediate contact with the material substances and elements that surround it. It is full of pores, covered with scales, perforated by the extremities of the perspiring and absorbing vessels, the ducts of the glands of the internal skin, and by the hairs. The nails and cuticle are connected, and in diseases of the skin, if the cuticle exfoliates, the nails are also pushed off; and after death, they *both* separate from the true skin underneath them, by maceration and putrefaction. The cuticle and nails are equally destitute of nerves and sensation. The nails are composed chiefly of a membranous substance, which possesses the properties of coagulated albumen, and contains a little phosphate of lime. Horns and nails have nearly the same component parts. The cuticle projects over the roots of the nails. The nails do not become scaly and exfoliate like the cuticle; they grow from a root like the hair, though they are evidently a continuation of the cuticle. The hairs grow from bulbous roots, situated in the cellular membrane, beneath the cuticle. The bulb is vascular, and connected by vessels with the cellular tissue. It consists of a double membrane, and the cellular texture lying betwixt them is filled with a bloody fluid. The hair arises from the bottom of the internal sac, and when a hair is extracted, if the sac or bulb be left entire, it will be regenerated. The European has the longest hair; the Asiatic next; thirdly, the American; and lastly, the African: men of a dark sallow complexion are generally hairy on the breast and shoulders. There is very little difference in the growth of hair and wool; wool grows thickest in summer, and finest in spring and autumn; the fleece becomes coarse and hairy in a warm climate. A hair appears to be a kind of tube enveloped in a cuticle, its surface is covered with scales; hence its disposition to entangle with other hairs. A hair which is soft and flexible, and loses its curl in moist weather, parts easier with its gelatine than a strong elastic hair, which retains its curl, and parts with its gelatine in small quantities, with difficulty. Black hairs are composed of an animal matter, which constitutes the greatest proportion,—a white solid oil, small in quantity; a grayish green oil, more abundant; iron, the state unknown; oxyde of manganese, phosphate of lime, carbonate of lime, very scanty; silica, and sulphur.

The human cuticle is white, and does not vary its *hue* in different individuals. It is as *colourless* in the African, as in the European; in the American Indian, as in the Asiatic. This fact may be easily proved, by a very simple experiment. If we apply a cantharides blister to a white man's skin, it raises the cuticle, by causing a fluid called the serum, to form underneath it; now the skin, raised by the blister, is the external *white coat,* which I am describing. If you apply a blister to a negro's skin, the cuticle (or external coat,) which rises up and covers the serum, is also *white,* as white as the cuticle of a Scotchman. This experiment proves, that it is not the external cuticle which makes the negro black; for his outward skin, or cuticle, is as white as the European's. The varied coloured skins of different individuals arise from other natural causes, which I will briefly explain, when describing the second coat. The cuticle is chiefly composed of a modification of coagulated albumen: coagulated albumen is that tasteless substance, which constitutes the outward portion of a boiled egg. In the negro, the internal surface of the cuticle is darker and softer than the external.

The second, or mucous coat, lies in immediate contact with the upper, and is composed of numerous blood-vessels and nerves, which give it exquisite sensibility. You cannot touch any part of your body where the cuticle is thin, without feeling a sensation of contact with the second coat. It is white in the European, and also in the infant negro, for about

six days after his birth. It then begins to secrete a dark coloured fluid upon its surface, which in the negro becomes black, and remains, *in statu quo*, until he dies and decomposes into his natural elements. This dark coloured secretion, shining through the thin external cuticle, gives the black hue to the African's skin. This secretion is *yellow* in the Asiatic, *red* in the American Indian, and *pale* in the European. The *thickened* cuticle on the palms of the negro's hands and the soles of his feet, by its obtuse opacity prevents this black secretion from shining darkly through it, and makes his thickened palms and soles appear much *whiter* than the rest of his sable body. The African's hue appears blackest on those parts of his body where the cuticle is thinnest. It is the pale secretion of this coat that makes the albino:* and its bilious secretion caused by obstructed bile, mingling with the circulating blood, makes the white man's skin appear yellow in jaundice. The varied secretions of this sensitive coat, modified by climate, constitution, and circumstances, give different colours to the different tribes of mankind. The physical causes of the varied coloured secretions of this mucous coat are not very accurately understood by physiologists. It cannot be the intense *heat* of the African's torrid climate *alone* that has made his skin so *black;* for the Esquimaux and Greenlanders are nearly as *dark* as negroes, although they live in an arctic climate of perpetual ice and snow; nor can it be *cold alone* that produces the sable skin; for the Finlanders and Norwegians, who live farther *north*, and in *colder* wintry climes than any of the inhabitants of the continent of Europe, are fairer in com lexion than any one of them all. The South-American Indians, who live on the summits of the Andes, exposed to perpetual cold, ice, and snow, are as dark in complexion as the inhabitants of the burning valleys beneath them, who luxuriate in indolence, on the soft, warm, flowery lap of everlasting summer. Something must be attributed to domestic and social habits, as well as to external circumstances; the face of the Highland peasant *girl* is dark-*brown;* the Highland *lady* is *white*. The constitutional diathesis of different families, tribes, and nations, is modified by education, political, domestic, and social circumstances, and physical causes; and *these* may produce all the varieties of complexion that distinguish individuals, families, and nations, from each other. Any one of these causes cannot *alone* induce all these changes; but the *whole, combined* and modified *individually* by their separate and *mutual* action on each other, may have produced every variety of complexion in the human species. In the negro, the inner part of the second coat is blacker than its outer surface.

This coat is also the seat of the pleasure and pain communicated by the sense of touch. It gives us painful sensations when irritated by external injuries; and pleasurable feelings, when stimulated by gentle contact with delightful objects. Its cruel laceration, from external violence, makes the sailor, the soldier, and slave, shrink with agony, when smarting under the infliction of the ignoble lash. It is also the sexual seat of pleasure in mutual kissing. The cold winter storm beating on its nervous sensibility makes us shiver. The summer sun, shining on its delicate *nerves*, makes us languid; without *it*, *man* would be incapable of appreciating pleasure and pain, by the sense of touch and contact with external bodies; and merely *exist* without sweet enjoyment. The earth, unadapted to his physical constitution, would be to *him* a dreary wilderness, where plants and lower animals alone could multiply and grow, and over-run its surface. But God, who adapts the *means* to the *end*, has made all things *right*. And every *person*, who understands the mechanism and physiology of his skin, will feel gratitude to the Eternal, and praise *Him* for *having made us as we are*.

Underneath the second, lies the third, or vascular coat. It is full of minute blood-vessels, and is best demonstrated when acutely inflamed. It is sometimes very much thickened by increased vascular action, and then it may be distinctly seen and examined, by ordinary spectators. It is the seat of the blood-vessels of the skin, and gives the red appearance to the cheeks, lips, and other parts of the body, where the external coverings are thin. It is the seat of the pustules of small-pox, with many other cutaneous diseases, especially those of an inflammatory nature, induced by extraordinary vascular action. In cases of *extreme debility*, such as typhus fever, purpura, measles, &c., it is the seat of the petechiæ, (or dark spots,) that appear like dots in the skin. These spots are caused by its minute exhausted vessels permitting more blood to escape, than its feeble absorbents are able to return quickly into the system; and they always indicate *morbid* debility. If these spots are formed of *venous* blood *alone*, the physical *debility* is not so extreme as when they are composed only of *arterial* blood; when venous blood is effused, they are darkly-purple; when arterial blood is effused, they are bright red, like scarlet, and are always a dangerous symptom, in the last stages of typhus gravior, if the patient belongs to the lymphatic temperament.

Beneath the third coat, lies the fourth, the cutis vera, (or true skin.) This is the thickest layer, and in lower animals is tanned to make leather; after death it is stripped from some of our larger domestic quadrupeds, and tanned for the purpose of making into shoes. In some monstrous wild animals, such as the hippopotamus and rhinoceros, it is so very thick, that it cannot without difficulty be pierced by an ordinary musket-ball. The true skin of the giraffe is an inch and a half thick. In the magatherium, an extinct animal that existed and perished *long* before the creation of *man*, it was more than two inches. This fact is not only demonstrated by many petrifactions of those animals' skins that have been found by geologists in the rocks that compose the interior strata of our globe; but also from the actual carcass of an entire animal, found a few years ago, imbedded in a deep layer of everlasting frozen snow, on the lofty bleak coast of Russian Siberia, and where it must have been buried by accident, at some remote undefined period of the ancient world; the icy grave was first disclosed by a large part of the coast falling on the beach, and leaving the animal exposed. The *cutis vera* binds down the soft parts of our bodies, protects them from violence and external accidents, and preserves their beauty, form, and symmetry, without any ungentle compression, nor does it irritate the most delicate organs that lie underneath it. Its composition appears to be a peculiar modification of gelatine, or animal glue.

There is another important use for the skin in the animal economy, than merely an external covering to the body. It is the organ by which perspiration is performed; and is, therefore, necessary for the continued vitality and health of our species, and of every animal that perspires.

Perspiration (or *sweating*,) is an excrementitious evacuation that requires to be constantly exhaled from the body, to free the blood from impurity, and to preserve animal life from immediate disease and premature death. About five pounds avoirdupois of perspired matter pass through the skin of a full-grown man every twenty-four hours.

There are two kinds of perspiration, sensible and insensible. The *sensible* can always be felt and perceived; for it constitutes visible *sweating*. The *insensible* passes off in the form of a *gas* or *vapour*, and we are not so conscious of its constant evaporation. Sweating is a secretion of the internal coats of the skin, which passes through the external *cuticle* by innumerable minute pores, imperceptible to the human eye, except by the help of a large microscope. When we see a person covered with large drops of *sweat*, we may rest assured that *they* have all passed through these *minute pores;* but having been perspired quicker than exhaled, they have accumulated on the surface, and are glistening on it like blobs of dew. Persons in this condition should not expose their bodies suddenly to a cold damp atmosphere; for *cold* causes the large drops to coagulate, closes the pores of the cuticle, and obstructs perspiration.

If we live in a cold atmosphere, where our perspiration is checked, our vital heat is retained. If in a warm atmosphere, where our perspiration is profuse, the heat of the body is discharged; hence the varied quantities of perspiration exhaled in warm and cold atmospheres help to equalize our animal heat, and make it suitable to the exigencies of the different climates to which we are exposed. The skin sympathizes with the lungs, bowels, and other internal organs, and generally renders them healthy or diseased, (in combination with other causes,) proportioned to the sanity, or morbidity of its natural functions.

The perspired matter is principally composed of water and carbon. It also holds in solution several salts and animal matter. The oxygen of the atmosphere, combining with the carbon, forms the carbonic acid thrown off by perspiration. Besides the *insensible* perspiration, there is also an *oily exudation* of the *glands* of the skin, which appears to bo useful in giving pliancy and softness to the scales of the cuticle. This oily secretion is very

* The albino is a white negro. The pale secretion of the mucous coat of his skin, which makes him white, is diseased.

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copious in the negro, and is a means of protection from the powerful influence of the sun, and prevents the crackling and breaking of the scales of his cuticle.

The negro's skin is remarkably *soft;* and this *softness* and coolness is observable in all the degrees of propinquity to his sable tribe. It has been proved by experiment, that *men* can preserve their existence, for a short time, exposed to the burning heat of two hundred and sixty degrees of Fahrenheit—and, on the other hand, that a ship's crew may winter in seventy-six degrees of northern latitude, and yet preserve their existence, when mercury and spirits are frozen by the intense cold. A very interesting account, of the best means for preserving the animal heat in extreme cold, may be found in Captain Parry's recent voyages near the north pole.

The skin so intimately sympathizes with the lungs, bowels, and other internal organs, that obstructed perspiration cannot very long continue without deranging their vital functions, and inducing disease. In the West Indies it is a common expression, 'when you cease to perspire *profusely, instantly* make your *will.*' Individuals who perspire *freely* have the best chance for an extended existence in a tropical climate. Those who perspire with difficulty generally die prematurely, if exposed to the torrid sun. The less a man perspires in a cold arctic clime (if only enough for animal purposes), the better; for his body thus preserves its vital heat, and is comparatively comfortable; while he who perspires *profusely*, shivers and perishes with cold.

Catarrh (or cold), in our damp climate, is generally preceded by obstructed perspiration. The best means for relieving the patient is promptly to restore it.

Some persons' skins are so extremely sensitive, and sympathize so intimately with their stomachs and bowels, that the sudden application of cold to their cuticle induces intestinal spasms. A case is related, in a Medical Journal, of a gentleman who could not draw up his buckskin breeches on his naked limbs, in a cold morning, without vomiting. The various spasmodic and inflammatory diseases that attack the different internal organs (arising from obstructed perspiration), depend, in a great measure, on the different temperaments of the individuals. In the sanguine temperament, the membranes of the lungs become inflamed or irritated; in the lymphatic—the glands of the lungs; and in the bilious—the stomach and bowels; hence the cause why different individuals are frequently attacked by diseases of different organs from obstructed perspiration; and why influenza induces a pulmonary affection in one person, bilious attack in another, fever in a third, &c., according to the constitutional diathesis of the patient. As the skin and its functions exercise such a very important influence on the physical condition of the individual, it is necessary, therefore, to preserve it from external injury, and keep its functions in a sound state, for the preservation of health, and prevention of disease. In our own chilly, damp, and ever changeable climate, we ought always to wear clean, dry, soft flannel, next our bodies. The upper part of our dress may be changed and agreeably suited to the seasons; but our *flannel* ought never to be removed, except at the close of the week, when we resupply ourselves with a clean one. This sanatory practice has been the means of preserving many thousands of beings during delicate childhood, and extending their longevity to old age.

The skin should be kept perfectly clean, and frequently washed and rubbed, to remove all external obstruction to *perspiration*, and keep the pores open for its free egress. Children should be wholly washed every day, and adults as often, if possible. Cold seabathing in summer, and a hot seawater bath in winter, are excellent remedies for the preservation of a healthy skin. If any internal organ be diseased, the cold bath is improper. In such a case, the hot bath relieves *internal* congestion, by expanding the cutaneous vessels, for the reception of a proper quantity of circulating blood. The cold bath, on the other hand, suddenly forces the blood away from the surface of the body, and by causing it to rush into the overloaded *internal* vessels, ruptures them if diseased, and sometimes induces immediate death. Fresh water may be employed for *bathing*, when seawater cannot be conveniently procured.

Sudden exposure to the cold, damp, night-air, especially on leaving a heated room, a crowded assembly, a warm church, a club for drinking toddy, a ball, or any other place where you have been sweating profusely, checks perspiration, and induces catarrh. The throat, the lungs, the bowels, the liver, or the brain inflame, according to the temperament of the patient, and, in a few days, another *unit* is added to the *dead*. If you would live long and enjoy health, avoid exposure to sudden cold when you are profusely perspiring, as you would shun the fangs of the rattle-snake, the poisoned arrows of the wild Caribb, and the bite of the rabid dog.

Persons residing in low, damp, ill-ventilated houses, with soft earthen floors, are very apt to suffer *severely* in cold weather (especially during the prevalence of sleet, rain, and easterly winds), from obstructed perspiration. This is one of the physical causes why typhus fever, inflammation, rheumatism, catarrh, and consumption, so frequently commit their direful ravages among the poor; and, combined with misery, intemperance, hunger, filth, and nakedness, has rendered mortality, in the pauper and crowded districts of large cities, *forty* per cent. greater, than in the *pleasant habitations* of the rich.*

This is a most important subject, and worthy the patient investigation of the medical philosopher and political philanthropist, and is now occupying public attention: we hope the time is not far distant, when useful sanatory regulations, for the prevention of increasing disease and mortality among the *poor*, and improving their condition, especially in over-crowded manufacturing cities, will be established by our legislature, in every town and district of the British empire. In the mean time, it is our duty to facilitate the progress of this great sanatory reform, by putting our "shoulders to the wheel, and helping it out of the ditch."

In my next *essay*, I will take up the Fascia and its uses, and the muscles with their muscular action, (*or mechanical power*). The muscles will also be illustrated by a corresponding Plate.

* In London, (in equal proportions of inhabitants,) 34 of the poor die of typhus fever, for only 13 of the rich; each of the poor, on an average, occupies about 35 square yards of surface; and each of the rich, 131 square yards. In Whitechapel, one of the most densely crowded of the districts of London, inhabited by the poor, one in 26 dies yearly; while in Hackney, a rich London district, the yearly mortality is only one in 52.

# GEOLOGY.

## CHAPTER II.

### PROOFS OF THE ANTIQUITY OF THE EARTH.

In our first chapter we alluded to the evidences of the Earth's antiquity, derived from the proofs of its original fluidity, and subsequent consolidation through the radiation of its heat into the regions of space, and those which spring from the fact, that, throughout a great many series of aqueous depositions there are traces of various extinctions and creations of organic beings, suited to the particular circumstances and conditions of the earth, at the time they were destined to live.

In walking over the surface of a country, we witness its undulations, its mountains, and its rivers, and are apt to conclude, that hill and valley, river and lake, may have existed in nearly the same condition since time began its ceaseless course. But when we come to examine the structure of the mountain, the causes of undulation, the alterations which have taken place in the water-courses, nay, even in the general configuration of the globe itself, or of any particular region of it, we naturally exclaim, "the hills themselves are the daughters of time, the waves of the present ocean played in past ages on other shores, and the rivers which now supply it are derived from surfaces, which in ancient days were below the level of the deep—all that is now land, is but the debris (1) of continents and islands now unknown, the wreck of a former world—the spoils and the sport of time." Effects have been produced, which, if attributed to the ordinary agencies of Nature, require the imagination to stretch its visual glance through the vista of a past eternity, or at least through a lapse of ages, as inconceivable in duration, as the distances of the spheres are in the field of space. Were we to assert that the present continents of Europe, Asia, Africa, and America, were once wholly immerged under the waters of the ocean, and that after rising at different spots in low new-born

islands, they gradually acquired their present configuration; nay, that the whole materials of which both the present continents and their islands are composed, have resulted from the denudation of continents and islands which have been worn away, or finally sunk under the all-encroaching influence of the waves, we would not be credited by many—the assertion would seem that of one whose avocation was the excitement of astenishment, and who, if he could make his readers wonder, had attained the acme of his ambition. Yet such, nevertheless, is the conclusion, to which all who study the structure of the earth, divested of prejudice and preconception are necessarily led. "At the first step we take in geological inquiry," says Dr Mantell, "we are struck with the immense periods of time which the phenomena presented to our view must have required for their production, and the incessant changes which appear to have been going on in the natural world; but we must remember that time and change are great, only in reference to the faculties of the being who notes them. The insect of an hour, contrasting its own ephemeral existence with the flowers on which it rests, would attribute an unchanging durability to the most evanescent of vegetable forms, while the flowers, the trees, and the forest would ascribe an endless duration to the soil on which they grow; and thus, uninstructed man comparing his own brief earthly existence with the solid framework of the world he inhabits, deems the hills and mountains around him coeval with the globe itself. But with the enlargement and cultivation of his mental powers, he takes a more just, comprehensive, and enlightened view, of the wonderful scheme of creation; and while in his ignorance he imagined that the duration of the globe was to be measured by his own brief span, and arrogantly deemed himself alone the object of the Almighty's care, and that all things were created for his pleasure and necessities, he now feels his own dependence, entertains more correct ideas of the mercy, wisdom, and goodness, of his Creator; and while exercising his high privilege of being alone capable of contemplating and understanding the wonders of the natural world, he learns the most important of all lessons—to doubt the evidence of his senses until confirmed by patient and cautious investigation."

We shall now proceed to lay before the reader some of the data connected with the stratification of the earth, which lead to the conclusion of a vast antiquity, and of the many physical revolutions it has undergone since it became a planet.

The rocks of which the crust of the earth is chiefly composed, occur in beds or layers; on examining these we find every evidence of their having resulted from matter carried by rivers into lakes, estuaries, or seas. This is demonstrable from some of them being composed of fragments of other rocks worn and rounded by the action of water, so as not to be distinguishable from the gravel strewed upon the shore, or which we meet with in the path of a mountain stream, except in its having been consolidated into a stony mass—such rocks are called conglomerates. The red sandstone formations of Arran, and the coasts of Argyle and Ayrshire, consist of immense beds of such rocks, alternating with layers of red clay, and red sandstone. This formation itself is many thousand feet thick; we never find in it any fragments of the coal, or of any newer formation; on the contrary, the conglomerates consist solely of pieces of quartz, slate, red sandstone, and other rocks of more ancient date. In the same formation, which stretches from Argyle through Stirlingshire and Forfarshire, to the eastern coast, remains of fishes in a very perfect state of preservation have been found. In both the conglomerates then, and in the fishes, we have evidence of this formation having been produced, not instantaneously, but through a long succession of ages. Each bed of pebbles, if the ancient agencies of nature were any way analogous to the present, must have been the work of many years. That these agencies were not more violent, or at least that there were long intervals of repose, is attested by the beds of fine grained sandstone, and consolidated mud, with which the conglomerates alternate. The largest of our existing rivers, in rainy seasons, carry great quantities of gravel, sand, and mud, into their estuaries or the sea; but great as the amount of debris is, the production of a quantity of matter, any way equivalent to that of the old red sandstones of Scotland or England, could not take place except in the lapse of innumerable ages. The mud carried down by the Nile, and deposited, amounts only to about a quarter of an inch thick annually. The old red sandstone is estimated at from three to four thousand yards in thickness. Allowing three inches as the average annual aggregation of matter, this formation could not have been deposited in less than 36,000 years. If we contemplate for a moment the agencies that must have been engaged in wearing down the surfaces of the ancient rocks, and in transporting them over the vast areas they now occupy, the time here stated will not seem any way exaggerated, but far too little for the amount of the effects produced. We have mentioned the old red sandstone as an instance, from which something like an idea may be formed of tho time requisite for the production of a certain class of rocks. The same, or still more decisive proofs of the lapse, and change of time are afforded by the other formations. The silurian (2) rocks underlay the old red sandstone of England, and these are also estimated at 3,000 yards in thickness. The slate rocks of Scotland are several miles in thickness, and all exhibit the marks of slow deposition and subsequent consolidation. We have traced a continuous out crop of these rocks along the coast of Argyle for seven miles, and this is not one-third part of its extent. The whole slate or schistose formations of the west Highlands of Scotland generally crop out in a north-west direction, and lie in an angle of from 45 to 70 or 80 degrees. They extend from about five miles below Dunoon, along the whole coasts of Loch Long and Loch Lomond, with nearly the same inclination. The slate rocks of England underlaying the silurian system, are also of immense thickness.

These facts show that, previous to the carboniferous or coal era, when the earth began to be adorned with vegetation, myriads of ages must have passed away.

The carboniferous (3) formation excluding the mountain limestone, millstone grit, (4) and coal measures, is estimated by Professor Phillips, at 1,900 yards in thickness. Many of the limestones in this formation consist almost entirely of organic remains. Beds of limestone, 20 or 30 feet thick, and totally composed of zoophytes (5) and shells of various kinds, are by no means uncommon in this formation: almost all the sandstones contain the stems of trees belonging to genera or species now unknown, and many of the clays abound with the most delicate impressions of the fronds and leaves of ferns, and other plants most delicately preserved; and fishes of enormous size are not unfrequently met with. Coal itself is now universally acknowledged to be of vegetable origin. The laminated nature of many of the sandstones, and of the shale or slaty clays, and their being frequently impressed with the ripple marks of the ancient waves, show that almost the whole of this immense mass of deposition was accumulated under the influence of comparatively tranquil water—if so, how immense must the time have been during which these deposits were formed. M'Culloch has estimated it at, at least 600,000 years!

The saliferous (6) or new red sandstone overlies the coal: it is about 9,000 feet in thickness, and yields evidence of similar conditions in the medium of deposition, as in the old red sandstone period. It contains besides red and variegated sandstones, marl (7) and conglomerates, immense beds of rock-salt, and layers of gypsum (sulphate of lime); it is in this series of rocks where the saurian or crocodile tribe are first found. The shells in it are all of marine origin.

The Lias (8) formation is superimposed upon the new red sandstone: it consists principally of limestone and shale, abounding with a vast profusion of organic remains, differing in species from any found in the older rocks.

The next formation is the oolite (9), consisting also of limestones and shales, and like the Lias, teeming with the evidences of a very different animal economy existing in the ancient from the modern ocean. Among these are the remains of the Ichthyosaurus (10) and the Plesiosaurus (11), animals combining the structure of a fish with that of the crocodile, and furnished with paddles like those of the whale. The character of these and the other animals will be described in their proper places—we mention them at present merely to show that time must have been required for their production and growth, and that any condition of the ocean, by which deposition would be much more hastily precipitated than now, would have been incompatible with the duration of their existence in the ancient seas. The remains of these and the other animals indicate every state of growth from youth to old age: all the species and many of the genera are extinct.

The oolite is succeeded by the Weilden, green sand and chalk formations measuring 660 yards in thickness, and containing

immense quantities of fresh water and marine remains, the species being almost all different from those in the older rocks, and none of them occurring in the newer. The Weilden is of estuary origin, containing many fresh water shells, and the bones of enormous reptiles ; one of which, the Iguanodon, must have measured 70 feet from snout to tail, and been 14 feet in girth round the body. The chalk and green sand abound with marine remains.

The chalk is succeeded by the tertiary deposits, in which the existing species make their first appearance. In the lower or first of the tertiary formations, there are only about 5 per cent. of existing marine shells ; in the second, or middle formation, the number of recent and extinct species is nearly equal ; in the last, or newest of these deposits, the recent shells amount to 95 per cent.—circumstances which sbow a gradual increase of marine animal life, for a long series of ages previous to our historical epoch. The tertiary rocks in the neighbourhood of Paris, and other places, abound with the remains of extinct quadrupeds allied to the tapirs with the bones of elephants, rhinoceroses, hippopotami, lions, tigers, and many other animals belonging to existing genera, but of different species from any now living. In none of these formations bave the remains of man or of his works been ever found, nor is there the slightest evidence from geological data, of his having existed for a longer period on the earth than is assigned to him by the Bible.

The facts we have stated, will, we think, satisfy the reader of the justness of the conclusion, that the whole stratified rocks which constitute the crust of tbe earth are derived from matter deposited by water at the bottom of the sea, in estuaries or lakes which at the time were inhabited by animals differing in species, and many of them in genera, from any that now exist ; and that consequently, the present structure and configuration of the earth is the offspring of a vast antiquity.

In the tertiary rocks, the number of species of fossil shells found is 2728. In the chalk rocks 500—in the oolite 771—in the new red sandstone 118—in the carboniferous rocks 336, and in the silurian and greywacke (12) systems 349 ; making in all, 4832 species. The greater proportion of these are as perfect in their structure as the living species. "The organic remains of plants and animals," says Prof. Phillip, "which abound in the earth are not those of the tribes which now live, but of many wholly extinct, and often of quite different races, different in form and structure, and consequently in the functions of life, though certainly belonging to a general system of nature founded on analogous principal conditions. Farther, it is not sufficient nor correct to say tbere is one living and one extinct creation. The plants and animals buried in the earth belong to many distinct and successive creations, which differ among one another no less than they almost all differ from the actual forms of life."

It is the delightful meed of Geology, to examine and study tbese monuments of ancient ages, and to extract from them something like a continuous history of the earth, from the time it became the receptacle of life to tbe present hour.

"To Astronomy belongs the investigation of the earth as a part of the planetary system, and the results, tbus reached, help to correct and limit geological inferences. Chemistry employs itself upon the inquiring into the laws and modes of mutual action among the particles of matter, and gives its results to aid in the general history of terrestrial phenomena. It is tbe province of Geology and Botany to arrange and interpret the facts connected with life and organization in plants and animals, and to these branches of knowledge, Geology owes immeasurable obligation. Thus, the study of the ancient history of the earth draws help from every kind of inquiry which man can make into the actual condition of nature, but robs none of its interest or glory ; on the contrary, by the novelty of its discovered facts, fresh problems are presented to the cultivators of natural science, and a perpetual excitement is kept up, which has proved of infinite service to them all."

(1) *Debris*, the waste of other rocks. (2) *Silurean*—from *Silures*, the name of the ancient inhabitants of Wales. The term Silurean is given to those rocks which occur between the clay slate and the carboniferous system. (3) *Carboniferous*, containing coal. (4) *Millstone grit*, a series of rocks in England, which lie between the mountain limestone and the coal measures, as the beds are called which contain workable seams of coal. (5) *Zoophyte*, a coral or sponge. (6) *Saliferous*, containing salt. (7) *Marl*, compound of clay and lime. (8) *Lias*, a provincial word, meaning layers. (6) *Oolite*, from *oon* an egg, and *lithos* a stone, given to this formation from some of its limestones containing little round particles like the roe of a fish. (10) *Ichthyosaurus—ichthys*, a fish, and *sauros*, a lizard. (11) *Plesiosaurus*, from *plesios*, nearly allied, and *sauros*, a lizard. (12) *Greywacke*, a name given to an indurated sandstone, belonging to the slate rocks.

# HISTORY.

## CHAPTER I.

### SOURCES OF HISTORICAL EVIDENCE.

The sources of historical information are eitber written records or the remains of the edifices and other works of the people of former ages. Another class, possessing to some extent the characteristics of both, consists of coins and monumental inscriptions, which are at once written records and fragments of the works of men which have survived those destructive influences incessantly at work to remove the remains of former times. This mixed class, however, is not so peculiar as to demand a separate consideration. These written records—books, or by whatever generic term we please to call them—which furnish information to tbe student of history, have either been compiled for the direct and avowed purpose of furnishing such information, or have been compiled for some other purposes ; the latter contain incidental statements of facts, important to the inquirer after historical truth, or expositions of opinions, or expressions of sentiment which cast an indirect light upon the modes of feeling and thinking peculiar to their age, highly conducive to a right understanding of its annals. The books compiled with the direct and avowed purpose of conveying historical information, are histories, (in a restricted acceptation of the word,) chronicles, biographies, memoirs, voyages, and travels ; and, in short, all works which profess to narrate facts in opposition to theoretical writings, and other works of the imagination.

Histories, properly so called, profess to narrate the fortunes of the whole or of some integral portion of a state, during a longer or shorter period of years. The very nature of their subject presupposes a certain amount of selection and generalization on the part of the historian. The very conception of a state or nation, is the effect of generalization ; for this name is not so much applied to one corporation as to a great many, the relationship between which is intimated by the name. The word state calls up to our minds a great number of people living together, and subject to the same system of organization or code of laws. To select any one point of time in which such a corporate body exists, and to prepare a statistical account of it as existing at the time, wbich shall be a correct likeness, is already no easy task. When we carry our minds tben to the task of tracing the actions and fortune of this corporate body through a succession of points of time, tbe difficulty of the undertaking seems almost unsurmountable. We not only want to know the different governments that existed, or to understand the laws whicb at various times were in operation ; but our inquiries extend to considering living, and suffering, acting individuals, continually changing in their condition, feelings, and actions, through a succession of years. The task of the historian, therefore, is to furnish us with such a picture of the existence of a nation as shall at once convey to us a knowledge of the frame-work of its society, its laws, and institutions, and its relations to other states ; and the manner in which men thought, felt, and acted in it. To fulfil these conditions is certainly no easy task ; and the fact is, that all histories are more or less imperfect— a fact which must be steadily kept in mind in order that we may be able to appreciate at its right value the information they contain.

The work of the historian, as already mentioned, is one of selection and generalization. He should omit many details that the attention of his readers may be concentrated upon what is characteristic and essential. He must generalise to present a picture of those emotions which were common to the great body of the citizens. But in doing this he must beware of losing himself in mere words of vague generalization. He should express those common feelings by examples, and select for his examples, such actions and sufferings of individuals, as, becoming generally known to all, had an influence on all, and gave a direction to the subsequent actions of the general body. A historian must know all, but must tell only a part ; and in what he does tell, he must ever keep in view that the adventures of any one individual, however great, or however estimable, are of no consequence for his purpose, except in so far as they illustrate national temper, or bave influenced national fortunes.

Some historians, and among these, by far the greater number of those belonging to the last and present century, content themselves with presenting biographical sketches of the successive rulers of a country. After reading their works, we are as much in the dark as before regarding the true history of the nation. We know neither the amount of its physical nor intellectual wealth, the amount of comfort among the citizens, nor the mode of its distribution. We are told of legislative enactments, but we know nothing of the circumstances which suggested them to the legislators, or how to appreciate their influence upon society. We are told of wars and conquests, but we know nothing of their effects upon the mass of society. We are only shown the results of a colossal struggle, while the strain upon the national sinews and nerves is passed over in silence. This class of historians err from an inadequate conception of what the history of a nation is. They confound the ruler with the state, forgetting that he is but part of it, and, in many cases, the mere puppet of circumstances. They seem to want a definite knowledge of the work they engage in; and, instead of carefully selecting and generalizing, so as to give a satisfactory history, they throw together masses of crude facts and opinions, some few of which may bear upon the general condition of the nation whose history they write, but the great majority of which tend little to form what may be called a *bona fide* history of a nation. There is another class of historians, men of higher intellect, and who have seen the emptiness of the class just described, but who, from a mistaken idea of what history ought to be, and in seeking to avoid the errors just alluded to, have fallen into others. Instead of histories, they have written commentaries; and instead of furnishing definite information, indulge in speculations and opinions of their own. Robertson's History of Scotland, and his History of America, are of this character. The first is a critical dissertation upon the guilt or innocence of Queen Mary—an essay upon one point of history rather than a history itself. Its remarks upon the value of evidence, its moral reflections, its estimates of character, are valuable; but narrative, the essence of history, is wanting. The qualities displayed in this narrative are valuable in preparing accurate narrative, but not as substitutes for it. Nor is it the business of the historian to obtrude his moral reflections. He should furnish the materials of thought, but has no right to prescribe how those materials should be used. The History of America is a still more gross misnomer. It is a long series of heterogeneous dissertations dove-tailed into each other; while America and the Americans are quite obscured by the curious disquisitions spun over them.

The great Italian historian, Davila, and the others, err in another way. They were almost all personally conversant with the affairs of state. They possessed an intimate knowledge of the laws and institutions, a practical intimacy with public business, and an insight into the human mind necessary to him who seeks to turn men to his purpose. But, indurated as they were in political intrigue, they regarded man but as a subject on which statesmen may operate and experiment. Their statements being biassed imperceptibly mislead the reader, who imagines that the manner in which they speak of the merits or demerits of men, refers to those men's moral worth, whereas it merely refers to their value as political tools. Another error such historians fall into is, that being subtile themselves, and always having an end in view in all their actions, they are apt to attribute intentions where none exist, and refined strokes of policy to minds incapable of making them. In their minds the great mass of men are but the playthings of governors, and the world, as it appears through their history, is a world of politicians, of cautious, profound, acute thinkers.

There is one historian who almost forms a class of himself—Livy. Possessing, as he did, an unrivalled talent for graceful and graphic description, his great work is the result of an instinctive impulse to exercise this power, and may be almost regarded as a prose poem. In those portions of his story which relate to the more refined periods of the Roman republic, it is curious to observe how the poet's instinct enables him to select the true and the characteristic, and to present us with a more correct and available narrative than the most subtle and painstaking thinkers have been able to do. In his narrative, however, of the earlier and ruder periods of the republic, the fastidious gentleman of the Augustan age cannot adapt himself to such calm habits of thought and feeling, and his substitute for critical examination becomes as useless as the needle where the magnetic law is suspended, and his history ceases to be trustworthy. These cursory remarks will suffice to show the student of history what use to make of the greater historians, and with what critical eye he must peruse their works.

Chronicle is a term applied to a particular class of records, of which the dark ages were amazingly prolific. These were in general compiled by some holy brother in the cloisters, then so numerous in Europe. Their minds, imperfectly trained under such preceptors as they had access to, enfeebled, moreover, by the unintellectual duties of their vocation, no great judgment is evinced, either in the selection of topics, or ability displayed in sifting truth from error. Theirs was a routine task of jotting down everything which they saw or heard, in the order in which they saw or heard them. The wondrous tale of the Palmer returned from the Holy Land; the perplexity of the convent, when a snow storm, by obstructing the access of the vassals, had reduced the holy fathers to short commons; the overthrow of a dynasty; brother Ambrose's happy suggestion, whereby the holy abbot's fit of the colic was cured; all come mixed together, with a most edifying postponement of every other principle of classification to that suggested by the order of time in which they came to the knowledge of the narrator. The chronicle of almost every convent is the work of many hands, one succeeding another in the task of noting events, and are of very varied value, some being worthless, while others, like the writings of the venerable Bede, almost rise to the dignity of history. What we can learn from histories is systematic, but abridged—an outline—a series of specimens. What we learn from the chronicles, is neither systematic nor complete: it is fragmentary and incoherent in the extreme, but here and there we stumble upon parts, racy, graphic, and full of that untransfusable truthfulness which falls to the lot only of the first teller of a story.

Biographies, or the lives of individuals, are another important source of historical knowledge. In the history of a nation, the most prominent actor only appears at intervals; nor would it be proper to enter into the minute details of his life, as this would distract from the general subject. Yet it is of great importance that the histories of individuals be regarded in studying the history of nations. General maps are necessary to give us a general idea of the nature of a country, its form and extent; but local maps and sections are also necessary, to give us a true notion of the minute details, that cannot be introduced into the general representation. Biographies are to general history, what local maps and sections, on a large scale, are to general maps; they are more full, minute yet clear in detail, and convey to our minds particular information, which enriches and extends the general ideas received from general information. Biographies of eminent men are useful, in so far as they inform us minutely of their character, and thereby enable us to judge how far the historian who treats of them is correct in his estimate of the actions he narrates, and the intentions he attributes, and thereby giving us a test of judging how far he is to be believed on other points. But there are other biographies scarcely less important. There is the biography of the man of science, pursuing his quiet, unostentatious labours, which, although not apparent on the surface, are the spirit of the state. There are the biographies of the poets, teaching us, by the manner in which their works were appreciated, the state of literature, of sentiment, of talent, of taste, and of feeling, which prevailed in their times. There are the biographies of artists, lawyers, divines, of all who, in less conspicuous stations than the statesman or warrior, form, nevertheless, in no less degree, the thinking and acting principle—the very soul, as it were, of the nation. In the difficulties they had to encounter in asserting and defending their station in society, we see the real history of the development of a nation's powers, intellectual and physical. Even the biography of the most unimportant individual is worth attention, being, as it were, a type of the general character of society, a sample of how myriads of sentient beings like himself thought and acted. It is in such works as these that we first become aware of the indispensable need of freedom to a great nation. It is only by the free play of individual energies that a nation can be made strong; and where the will of one, or a few, becomes irresistible, this play is necessarily checked. The momentary show of energy in such a state, is the energy of the madman strangling himself with his own hands. The struggle is terrific, but produces only paralysis and death.

Memoirs are a kind of cross-breed between the chronicle and

the biography; sometimes appertaining more nearly to the one, and sometimes to the other. They present us with fragmentary, superficial views: there may be little of positive truth in them, but they are the tenor of conversation, and mode of sentiment, amid which the active and influential spirits of the age were developed, and as such they enable us to enter into and appreciate their feelings in a manner no other writings eould do. They "show the very age and body of the time, its form and pressure."

The importance of voyages and travels is derived from the fact, that the contemporary historian, regarding the laws and eustoms of his age as things of course, and forgetting that a time must come, when to a differently constituted society these familiar things would be obsolete, strange, and unintelligible, is apt to make reference to things which, although known and understood in his day, would be inexplicable to posterity. The contemporaneous historian, whose evidence, as nearest the fountain-head, is most valuable, runs imminent danger of becoming more or less unintelligible, by the change in social institutions, and eonventional modes of thinking and speaking. He cannot project himself into futurity, to know in what language and in what mode to express himself; neither can he know what things are to become obsolete or misapprehended by his posterity. Now, what the contemporary historian cannot do for himself, the transient visitor from another land may do. Although the traveller, from superficial information, cannot enter into the systems which bind the states he visits together, he is struck with the dissimilarity which he finds between their customs and institutions, and those of his own land. These strike him as something new, strange, and peculiar, and he depicts them graphically, and sometimes with startling effect. Posterity, by taking the contemporary historian for the expression of the inner spirit of his age and country, and the contemporary traveller for the picture of its outer form, can make the one supply the wants of the other, and furnish between them a more animated counterpart of what has ceased to exist.

So much for written records compiled for the avowed purpose of furnishing historical information. We may now turn to works of system or of imagination, from which we may glean incidental statements of facts or unconscious illustrations of the modes of thought or general condition peculiar to our age.

In systematic works, facts of this kind are sometimes stated as the basis of argument. Thus, Aristotle's treatise on politics will be found to contain much valuable information regarding the organization and power of different states, contemporary with that philosopher. The Memorabilia of Socrates, on the other hand, compiled by Xenophon to vindicate the character of his illustrious master, contain many little narratives, which throw important light on the domestic manners of the age, and on the sentiments which animated its public characters. The writings of Plato are rich in similar illustrative passages. There are other and still more correct pieces of information to be derived from systematic works. Thus Quintilian, laying down his precepts for the early education of the future orator, cites the opinions of several of his predecessors, as to the period at which the training of the infant mind should commence, and the most expedient mode of training. These furnish us with opinions of distant ages on the question of education, for which we might have sought in vain, in the works of contemporaries. Again, Claude Ptolemy, a name famous in the annals of astronomy, has left us, in one of his works, an historical account of the most accurate and important astronomical observations previous to, and during his own life; by these, he has furnished us with the means of ascertaining to a certainty, many important dates; of introducing order and regularity into the history of periods, during which, obscurity and perplexity must otherwise have existed; and of testing the trustworthiness of many assertions, by scrutinizing their chronological accuracy.

Imaginative writings are chiefly valuable as enabling us to think and feel with the people of the age in which they were written. They convey to us a correct impression of the daily life of the men of their day. They are constructed of fragments of real life, combined into an imaginary whole. There never was such a man as Sir Roger de Coverly; but many an English squire of his day, too old for the boisterous sports of youth, has rode a-field, as he did, to gentler exercises, followed by the blessings of old and young. There have been many Will Wimbles, in whom a warm heart, an active and generous disposition, have been allowed to run to waste by the prejudices of caste. Black George, the poacher in "Tom Jones," has a truth beyond the heroes of many a story, meant to be correctly narrated. How many Amelias have sat watching through the weary hours of night for the return of a truant husband? Or, turning to the imaginative writers of another land in our own day; does not Andrew the Savoyard, convey a juster notion of the internal life of one circle of society in Paris, and among the primitive peoplo of Savoy, than history could do? Turn back to the writers of olden times, and in the exuberant richness of Aristophanes' effervescent spirit, when he sets his clod-hopper to offer sacrifice on the return of peace, we are made to feel, as none but the poet could make us, the happiness which animated the olive growers of Attica, when the genius of war ceased to animate nations.

We now come to the works of men, considered as sources of historical information. Everything bearing the indisputable traces of man's handy-work, is a proof that men existed who produced it; and, if it be a solid structure, as the remains of a building, it is a proof that the men who produced it existed upon that spot where it is found; the form and arrangement of the remains, the amount of dilapidation (taking into account any show of violence that may appear to have hastened the decay) enable us to conjecture the age and object of the original building. The traditions of the country may carry us further on our conjectural path. So far we have only guess work. But if we possess accounts, more or less authentic, of the erection of certain structures in particular places, and if we find remains in the places agreeing more or less with the written accounts transmitted to us, then those remains are elevated to the dignity of historical records, and become important links in the chain of evidence by which we seek to establish historical truth. They are merely subsidiary sources of information to the written record, but once animated by its touch, they give to it a fulness of additional information, at least as much as they receive from it.

The most striking instance of historical monuments of this kind is furnished by the pyramids of Lower Egypt. In the writings of the oldest profane historian, Herodotus, we have a description of certain peculiar structures standing on the banks of the Nile; and, turning our view to that locality, we find structures exactly such as he describes still existing there. The pyramids corroborate the narrative of Herodotus; they prove on one point he is trustworthy, thus affording a presumption in favour of the accuracy of other points of his narrative. And they do more than complete the tale he has furnished us with, of the times, old even to him which saw thom reared; for the curious and persevering research of the present century has taught us more about the structure of the pyramids, than was known to Herodotus. Travelling from the south-east, we find in the still remaining Parthenon of Athens, important elucidations of the Greek historians. The Collosseum is no unmeaning chapter of the Roman history. And, even in our own land, a systematic and persevering examination of the line of the Roman wall, and the neighbouring remains of rude forts, traced by tradition and written records to the Roman invaders, would throw much light on the history of the first civilization of our land.

There are other kinds of remains, such as pieces of sculpture, which, being capable of removal, we cannot affirm with certainty to have been produced on the spot where they are found. There is, however, a national character in such works, enabling us to refer them with considerable certainty to their real authors. But not only do works of art carry in them this internal evidence as to their real local origin, they bear also marks by which we may, within certain limits, determine their age. The power of referring a product of art to its infant, mature, or declining period, each of which are easily distinguishable from one another, coupled with the indications found in written annals, enable us, besides fixing its native country, to approximate to the time of its formation.

We now come to the class which adds something of the character of written records to the mere monumental. There are inscriptions (funeral and others), coins, books, (meaning the material of books, not what is written in them,) and we may add laws. Such inscriptions as are found on the spot where they were originally placed are especially valuable. Coins or inscriptions, removed from their original situations, are only less valuable through the circumstances of the removal rendering it

more difficult to establish their authenticity. Manuscripts, of which the age can be proved by external evidence, are at once written records and specimens of the handywork and prosperity of the age in which they were fabricated. Laws, even apart from the stones or metals on which they may be graven, or parchment, papyrus, or papers, on which they may be traced, are, strictly speaking, monuments of the age to which they belong. They are not a narrative or description of what then was law, they are that law itself. There are a number of other more trifling monuments of antiquity which throw light upon the domestic and public life of past ages, which, however, will be spoken of when prefixing a *catalogue raisone* of each section of the illustrative historical sketch.

Having now indicated the sources upon which the mind has to work in order to build up the structure of its historical knowledge, our next article will be devoted to pointing out the laws, in conformity to which, it must operate upon these sources of information, if it would be sure to extract truth from them. After having discussed this, the reader will be able to appreciate the truth, that historical knowledge is not to be found and cannot be contained in any written work, but can exist alone on the living pages of a mind, which has laboriously and conscientiously culled it from among the confusion of partial sources, throughout which its fragments lie scattered.

## BIOGRAPHY.

### GALILEO.

Galileo Galilei, the eldest son of Vincentio Galilei, was born at Pisa in Italy, on the 15th of February, 1564. Like most experimental philosophers, Galileo, in his earliest years, gave indications of that bent of mind, and intellectual superiority, which has made him rank so high among the philosophers of antiquity. Although his father was by no means wealthy, Galileo received a tolerable education. He was desirous of following the profession of a painter; but in obedience to his father's desire, he entered as a scholar of arts at the university of Pisa, on the 5th of November, 1581, and applied himself to the study of medicine. Music was a favourite study of Galileo's. In studying the principles of this science, he found it necessary to learn something of geometry, and commenced to Euclid's Elements. The demonstrations of the mathematician, and the new and wondrous truths which this science unfolds, took such hold of the ardent mind of Galileo, that after many fruitless attempts to confine him to the study of medicine, his father gave up the attempt, and allowed him to follow his own inclinations. From Euclid he ascended to the higher mathematicians; and, while studying Archimedes' treatise on hydrostatics, he wrote an essay on the hydrostatical balance, explaining its construction, and the mode by which the philosopher of Syracuse detected the fraud committed by the jewellers making Hiero's crown. This work introduced Galileo to Guido Ubaldi, an eminent mathematician, who engaged him to investigate the subject of the centre of gravity in solid bodies; and the treatise which he produced upon this subject was the foundation of his future celebrity.

Through his connexion with Ubaldi, Galileo was appointed lecturer on mathematics at Pisa in 1589, with a yearly salary of sixty crowns, which he increased by devoting some time to private teaching. At the early age of eighteen, Galileo doubted the philosophy of Aristotle; and on his establishment at Pisa, commenced to overthrow the doctrines of this philosopher. His first inquiries were into the mechanical doctrines of Aristotle, which he soon discovered to be untenable. The errors which he found existing, he exposed to his pupils, and a rancorous controversy commenced between the followers of Aristotle on the one side, and Galileo and his pupils on the other. Argument, and even experiment, failed in convincing Galileo's opponents. The doctrine of Aristotle, that the heavier of two falling bodies would fall quicker, was disproved by the experiment of dropping bodies of different weights from the leaning tower at Pisa; but although these bodies struck the ground nearly at the same instant, the followers of Aristotle remained unconvinced, or at least unconverted. Conscious of his superiority, and the truth of his doctrines, Galileo turned not only the powers of argument, but the shafts of ridicule and sarcasm against his opponents; thus raising up a personal enmity, which afterwards developed itself in bitter persecution. Other circumstances increased the rancour of his enemies, and at last made his position so uncomfortable, that he gave up his situation at Pisa, and accepted the professorship of mathematics at the university of Padua, with an income of 180 florins. The death of his father having burdened Galileo with the family, he had to apply himself here as at Pisa to private teaching. Notwithstanding his public and private duties, however, he still found leisure to make several discoveries and inventions, which were circulated in manuscript amongst his friends. Some of these abused the confidence reposed in them, and published several of Galileo's inventions as their own.

The doctrines of Copernicus, regarding the stability of the sun and the revolution of the planets, were the subject of disputation among the learned in the time of Galileo. He early became a convert to the new doctrines, and believed in them even at the time he was teaching the opposite or Ptolemaic system, which regarded the earth as stationary, and the sun a revolving body. Shortly after he went to Padua, he published a treatise on the sphere, in which the system of Ptolemy was supported by the very arguments which he afterwards ridiculed. It is rather considered, however, that it was sometime after the publication of this treatise that Galileo changed his opinions. About this time he commenced a correspondence with Kepler, the German astronomer, which continued till his death.

In 1593, he contracted a chronic disorder, from inadvertently sleeping at an open window, which afflicted him at intervals during the rest of his life. At this time, Galileo's reputation as a philosopher was widely extended all over Europe, and many of the nobility became his pupils. His first engagement as professor at Padua was for six years. On the expiry of this term, he was re-engaged for other six years, at an advanced salary of 320 florins.

The first important discovery of Galileo was, that the vibrations of a pendulum are performed in equal times, whatever be the size of the arc described, within certain limits. In 1604, a new star was discovered by astronomers in the constellation of Ophiuchus, and formed the subject of much speculation. By some it was set down as a meteor; but from the absence of parallax, Galileo proved it to be one of the fixed stars, situated far beyond the bounds of our own system.

Galileo was again appointed professor at Padua, in 1606, and his salary increased to 520 florins. So great had his fame as a philosopher arisen, that the lecture-room could not contain his hearers, which obliged him often to lecture in the open air. Among other pursuits he investigated the properties of the loadstone, and discovered a method of arming them so as to double their magnetic power.

Galileo still kept up communication with the family of the Duke of Tuscany, who had been his early patron. Cosmo, who had succeeded his father Ferdinand, had been one of Galileo's pupils, and being imbued with an ardent wish to promote science, formed the desire of attaching his former master to his household.

Negotiations were accordingly commenced. His salary as professor at Padua was to be greatly increased on the expiry of his engagement. The seclusion of private life, however, offered far greater charms to the studious philosopher. He was anxious to escape the performance of public and private duties, which continually interrupted his own studies. He accordingly accepted the situation of philosopher and principal mathematician to the Grand Duke of Tuscany, with a salary of 1000 florins, and took up his residence at Florence. The only duties attached to this situation, were, to lecture occasionally to sovereign princes. It was expressly stipulated that he should have the most perfect command of his own time, to devote to study and the completion of some projected works.

During the progress of the arrangements for leaving Padua, Galileo paid a visit to Venice. Here he became informed of an optical instrument, presented by a Dutchman to Prince Maurice of Nassau, which possessed the property of enlarging objects, and bringing them nearer the observer. This was confirmed by a letter which Galileo received a few days afterwards from Paris. To the consideration of this subject he immediately applied himself, and the first night after his return to Padua, he discovered what he sought in the doctrine of refracting light. He fitted a

spectacle-glass to each end of a leaden tube, one of which was plano-convex, and the other plano-concave, and on applying his eye to the concave glass, he found that it magnified. Delighted with his discovery, he carried his little instrument in triumph to Venice, where it created a most intense excitement, and for a month thousands flocked to see it. He made a present of it to the Venetian senate, and received in return a perpetual grant of the professorship at Padua, and an increase of salary from 520 to 1000 florins. It was shortly after this that he entered the household of the Grand Duke of Tuscany.

After disposing of his first instrument, which magnified only three times, Galileo applied himself to the making of another which magnified eight times, and "at length," as he says himself, "sparing neither labour nor expense," he constructed an instrument which magnified thirty times. With this instrument he discovered the inequalities in the moon's surface. "The dark and luminous spaces he regarded as indicating seas and continents, which reflected in different degrees the incidental light of the sun; and he ascribed the phosphorescence, as it has been improperly called, or the secondary light which is seen on the dark limb of the moon in her first and last quarters, to the reflection of the sun's light from the earth." With the telescope he discovered a striking difference between the appearance of the fixed stars and the planets. The latter exhibited round and well defined discs like the moon, while the former, even of the first magnitude, appeared but as lucid points. He was likewise enabled to resolve portions of nebulæ and clusters, which appeared to be hazy spots in the heavens, into distinct and numerous stars.

On the 7th of January, 1610, he discovered three of Jupiter's satellites. When he first observed them, two were on the east side, and one on the west side of the planet, all in a straight line, parallel to the ecliptic, and much brighter than fixed stars of their magnitude. He regarded them at first as fixed stars; but, on chancing to direct his attention to them again on the 8th of January, he found all the three to be on the west side of Jupiter, and nearer each other. Disregarding the circumstance of these stars having approached each other, he considered how Jupiter could be to the east of them, when the day before he had been to the west of two of them; and the conclusion he came to was, "that the motion of Jupiter was *direct* contrary to astronomical calculation, and that he had got before these two stars by his own motion." On the 10th, however, another observation showed him only two stars, and both on the *east* side of Jupiter. It was evident that the planet could not have moved from west to east on the 8th of January, and two days after have moved from east to west. Under these circumstances he came to the conclusion, that the different appearances arose from the motion of the stars themselves. On the 11th, there were two stars on the east side of Jupiter, but the one was twice the size of the other. "This fact threw a new light upon Galileo's difficulties, and he immediately drew the conclusion which he considered to be indubitable, 'that there were in the heavens *three stars*, which revolved round Jupiter in the same manner as *Venus* and *Mercury* revolve round the sun.'"* On the 13th, Galileo discovered the fourth satellite of Jupiter. Having made these discoveries, he named them the *Medicean stars*, in honour of his patron, Cosmo de Medici, grand duke of Tuscany, and published an account of them in a work entitled the "*Sidereal Messenger.*"

These discoveries, the fruits of the newly discovered telescope, astonished the whole scientific world. The ideas, however, which Galileo enunciated in his "Sidereal Messenger," were attacked on all hands by the Aristotelians. They even denied the existence of the four satellites which Galileo had discovered: some affirming he was deceived by reflected rays; and others, that it was a *ruse* to afford himself a subject for discussion. Their existence having been at last indisputably established, others began to claim the priority of discovery, and to pretend that they had discovered additional satellites of Jupiter. Some gave this planet as many as twelve moons; but they were gradually found out to be fixed stars, and Galileo remained the original discoverer of the four secondary planets.

Before the close of 1610, Galileo discovered Saturn's ring, although not conscious of its true nature, or the appearance which it presents when highly magnified. He described Saturn as a triple star, each retaining its relative position. Shortly after, he discovered that Venus presented phases like the moon, when at different parts of her orbit. He likewise discovered spots on the sun's surface, from which he calculated that that luminary had a motion on its axis, completed in about twenty-eight days. In 1612, he published a treatise on floating bodies, displaying a knowledge of many true principles in hydrostatics. It was violently attacked; but the master-mind of Galileo refuted his opponents as soon almost as they appeared.

The great objection raised by the priesthood and followers of Aristotle, against the doctrines advocated by Galileo, was, that they were contrary to Scripture, and ran counter to the doctrine of the church. In refuting these and other objections, Galileo added to the calm arguments of reason the bitterness of sarcasm. In 1613 he published a letter to prove that the Scriptures were not to be taken as guides in philosophy, and that the language found in the Bible was wrong interpreted, and might with equal propriety have been urged against the doctrines of Ptolemy. The storm which had been gathering over the devoted head of the philosopher at last broke forth. He was denounced from the pulpit by one Caccini, a friar. The general of the order to which this friar belonged apologized for this attack; and, stimulated by a strong love of truth, and to silence his antagonists, Galileo published another letter defending his views of Scripture, as applied to his own and the system of Ptolemy.

These letters were denounced to the Inquisition, and steps taken to bring Galileo before the bar of that sanguinary tribunal. It is a disputed point whether Galileo, on hearing of the steps taken against him, went to Rome of his own accord, or whether he was cited there. He appeared at Rome at the latter end of 1615, and was shortly after summoned before the Inquisition, to answer the charges of having heretically maintained the motion of the earth, and the stability of the sun, and with having taught it to others. The Inquisitors met, and after considering these charges, decreed, that Galileo should be enjoined to renounce those opinions, and to pledge himself neither to teach, defend, nor publish them; and that, in the event of refusal, he should be thrown into prison. To these Galileo agreed, and was thereupon dismissed.

Philip III., king of Spain, a country at that time extensively engaged in maritime enterprise, had offered a reward for the discovery of an improved mode of finding the longitude at sea. To this problem Galileo turned his attention, and proposed to make the satellites of Jupiter subservient to effecting this purpose. Communications on the subject were made to the Spanish court, and so great was Galileo's desire to carry out his project, that he offered to go to Spain, and reside there till he had communicated a knowledge of his method. Nothing satisfactory came out of these negotiations, which were occasionally revived during the period of ten or twelve years.

In 1618, three comets visited our system, and engaged the attention of the learned men of the time. Galileo was prevented by illness, from making observations on these erratic bodies; but he became deeply involved in controversy respecting them, and, it is asserted, maintained the opinion that they were meteors.

Cardinal Maffeo Barberini, a sincere friend of Galileo's, was raised to the papal throne; and, although in ill health at the time, Galileo set out for Rome, to congratulate the new pope on his elevation, and secure a continuation of his friendship. He was kindly received; and after repeated audiences, the receipt of several presents, and the promise of a pension to his son, he was dismissed by the pope with every expression of friendship and regard.

Galileo was scarcely free from the fangs of the Inquisition, than his innate love of truth, and abhorrence of a system which set the erring judgment of men superior to the dictates of reason and the phenomena of nature, prompted him to repeat his offences. In 1618, he communicated to the archduke Leopold his theory of the tides; and, in doing so, alluded, in sarcastic terms, to the proceedings of the church. The same spirit pervaded others of his writings. In 1632, he published a work, under the title of *The System of the World of Galileo Galilei*, demonstrating the Copernican theory. To shield himself from Inquisitorial persecution, he adopted a system of dialogue, in which three assumed characters are exhibited in debate upon the respective systems. One of these takes up, and defends the system of Copernicus; another suggests doubts and difficulties; and the third stands up for the system of Ptolemy. This work attracted great notice, and the church having committed itself by denouncing the

* "Martyrs of Science," by Sir D. Brewster.

new doctrines, at once laid on its strong arm to crush the audacious innovator on its dogmas.

Proceedings were immediately adopted to summon Galileo again before the Inquisition. Representations were made through the Tuscan ambassador at the papal court, to obtain a written statement of the charges, that Galileo might prepare for his defence. This, however, was refused, and a summons was soon issued for him to appear at Rome. At this time a contagious epidemic was raging in Tuscany, and a strict quarantine was enforced at Rome. Representations were made of the miseries which a journey under these circumstances would impose upon Galileo, who at the time was suffering from advanced age and ill health. Personal attendance was however peremptorily demanded. Some respect was certainly paid to the talents and infirmities of Galileo during the progress of his trial. He was allowed to reside in the palace of the Tuscan ambassador, and even permitted to visit the public gardens.

On the 22d of June, 1633, the Inquisitors assembled to pronounce sentence on the philosopher. From passages in the sentence, it is suspected that Galileo was put to the torture. The sentence itself is too long for insertion; but the following extract will convey an idea of its nature.

"By the desire of his Holiness, and of the most eminent Lords Cardinals of this supreme and universal Inquisition, the two propositions of the stability of the sun and the motion of the earth were *qualified* by the theological qualifiers as follows:

1st. "The proposition that the sun is the centre of the world, and immovable from its place, is absurd, philosophically false, and formally *heretical;* because it is expressly contrary to Holy Scripture.

2d. "The proposition that the earth is not the centre of the world, nor immovable; but that it moves and also with a diurnal motion, is absurd, philosophically false; and theologically considered, at least *erroneous* in faith.

* * * * * * *

"We decree that the book of the Dialogues of Galileo Galilei be prohibited by edict; we condemn you to the prison of this office during pleasure; we order you for the next three years to recite once a-week the seven penitential psalms."

Had Galileo stood up boldly in defence of his opinions, he might not perhaps have disarmed the persecuting spirit of the Inquisitors, but he might have confounded their accusations, and either stood the free champion of truth, or fallen the proud martyr of science. He had observation and experience on his side against which no one could shut his eyes; he had arguments to advance which could neither be eluded nor contradicted; and more, he had the precedent of the church itself acknowledging, and in a manner patronizing the very opinions for holding which they were persecuting him. At the very moment that he stood clothed in penitential sackcloth before the bar of the Inquisition, the work of Copernicus (himself a catholic priest), dedicated to the Pope, stood in the library of the Vatican; and in the very year of Galileo's first persecution, a work was issued by a Carmelite monk at Naples, upholding the same opinions, and its author never called in question. By confessing to the charges of the Inquisition, Galileo in a manner justified its proceedings. And, however detrimental it may have been to the interests of science, however degrading to the spirit of humanity, we must look upon the ancient philosopher with a kindly eye. He lived in a time when the mind of society was bound down in reverence and fear to the dictates of the church. His expanded mind might in its vigour have braved persecution, and even death, before perjuring himself in the eyes of the world. But old age had laid its withering hand upon him; physical suffering had broken down his frame; and, dreading to sigh out his few remaining days in the lonely dungeons of the Inquisition, he quailed before the dread power of that fearful institution, and passively renounced, in words, those opinions which he knew to be true, and which the progress of science has since demonstrated. On his knees, and with his hand upon the Scriptures, he solemnly abjured the opinions he had taught.

"With a sincere heart and unfeigned faith, I abjure, curse, and detest, the said errors and heresies, (viz., that the earth moves, &c.) I swear that I will never in future say or assert anything, verbally, or in writing, which may give rise to a similar suspicion against me.

"I, Galileo Galilei, have abjured as above with my own hand."

Rising from his knees, Galileo, it is said, stamped with his foot upon the ground, and whispered to a friend, "It does move though."

Immediately on the ceremony being concluded, Galileo was conducted to the prisons of the Inquisition. The abjuration and sentence were publicly read to the principal universities. After four days' confinement, the interest of the Duke of Tuscany procured his liberty to reside under surveillance in the house of the Tuscan ambassador, from whence he was shortly removed to the palace of the archbishop Piccolomoni at Sienna. Here he resided six months, and was kindly treated; he was then permitted to return to his own home, near Florence; still, however, under restraint. Shortly after returning home, Galileo suffered great affliction from the loss of his favourite daughter. From 1634 to 1638, he remained a prisoner in his own house, during nearly the whole of which time he suffered greatly from ill health—every application for a remission of his sentence being rejected.

In 1638, he obtained leave to visit Florence, for the benefit of his health; but under such strict terms, that he dared neither visit his friends nor admit them to his house, and required even a special order to be allowed to attend mass. From 1633 to 1638, Galileo, who applied himself as closely to study as his health would permit, composed his "Dialogues on Local Motion." So fearful were his enemies that the true spirit of the philosopher might again break out, that a licence was not granted for its publication, and it had to be printed in Holland.

About 1636, Galileo discovered the moon's diurnal and longitudinal libration. This was his last telescopic discovery. He had for years been afflicted with disease in the right eye; in 1637, his left was also attacked, and in a few months the bodily eyes of the philosopher were darkened for ever. After publishing his Dialogues on Motion, he renewed his attempts to introduce his system of finding the longitude at sea. He made offers to the Dutch government, who appointed commissioners to investigate the subject. This correspondence ended in nothing. Galileo was presented with a golden chain as a token of respect; and after his blindness, one of his pupils undertook to arrange and complete his calculations and observations. All parties engaged in this matter died before it could be brought before the world This, however, is the less to be regretted; for the method proposed has never yet been found answerable to the desired purpose.

After Galileo had become blind, the Inquisition exercised a little more lenity towards their victim. Many eminent men of the day visited him, amongst whom was our countryman, Milton. He projected a continuation of his Dialogues on Motion; but, while preparing it, he was seized with his last illness, and in two months the spirit of the injured philosopher was removed from the enmity of his persecutors.

Not content with striking him down while living, the vengeance of the Inquisition followed Galileo even in death. His right to make a will, and of being buried in consecrated ground, was disputed; and although these were withdrawn, his friends were prohibited from erecting a monument over his remains, and his body lay for thirty years buried in an obscure corner of the church. In 1737, his body was exhumed and re-interred under the splendid monument which now covers it. On this monument is a bust of Galileo, and figures of geometry and astronomy. His house at Arcetri, about a mile from Florence, still remains, an interesting relic to lovers of science.

## ARMSTRONG'S HYDRAULIC CRANE.

Plates III. and IV. present our readers with the result of Mr. Armstrong's labours, in the application of a column of water as a prime mover, and as a substitute for the great bulk of the present imperfectly performed manual operations.

The earliest successful attempt to employ other than muscular force to raise weights, appears to have been made by Mr. John Hague of London, who connected the chain by which the weight was to be raised with a piston fitting a cylinder. A vacuum was formed in the cylinder by steam power, and the weight was raised according to the area of the cylinder and the degree of exhaustion. Several cranes, even some distance apart, were thus worked by one

engine, the exhaustion in the crane cylinder being effected through pipes carried under ground from the engine to the cranes. The communication between the main and the crane was opened or closed by valves, whereby also the speed with which the weight was raised and lowered could be regulated with perfect control, and almost without an effort.

Hague's system did not gain much in practice, and Mr. G. W. Armstrong, of Newcastle-upon-Tyne, has successfully introduced the hydraulic crane here illustrated, and of which a beautiful model is in the Exhibition, standing in the catalogue as No. 44, Class V.

This crane is worked by water, deriving its force from the elevation of the reservoir.

In addition to the Crane, as adapted for harbours, &c., our plates exhibit the application of the scheme to the hoisting and moving of goods in warehouses and stores where, unlike the primary example, a great rise is required.

Plate III. represents a front and side elevation of the cranes as erected at Newcastle, together with various details of the machinery.

Fig. 1, represents a side view or elevation of the crane.

Fig. 2, is a view taken at right angles to the preceding figure.

A, is a cylinder containing a water-tight piston attached to the piston-rod B. C C, is a feed-pipe which communicates with the main supply pipe D, and by which water under pressure is caused to enter or escape from the cylinder, as the case may be, the direction of the flow being determined by the action of a box slide-valve E. $D^1$ $D^2$ and $D^3$, are three sheaves or pulleys, two of which, namely, $D^1$ $D^2$, turn on fixed bearings, while the remaining one $D^3$, travels with the moveable carriage F, attached to the end of the piston-rod B, the said carriage F, being supported upon the friction-rollers G G, two of which are placed at each side of the carriage, and run upon rails, H H, also placed at each side of the carriage. I, is a hollow cast-iron pillar, forming the fixed centre, round which the moveable parts of the crane turn, and *t t t* is a cast-iron frame, having the pillar I attached to it; this frame is bolted to the foundation. J J, is the chain to which the load is suspended; this chain passes downwards through the centre of the pillar I, and after passing over the pulleys $D^1$ $D^2$ and $D^3$, as represented in the drawing, is fixed to one end of the moveable carriage F. See also fig 8. Now it is evident, from this arrangement, that when water conveyed in the pipe D, from any sufficiently elevated source, is admitted into the cylinder A, through the feed-pipe C C, the piston and rod B, will be put in motion by the pressure of the water, and at the same time will lift the load attached to the end of the chain, while the extent of the piston's action being multiplied threefold, by means of the sheaves or pulleys $D^1$ $D^2$ and $D^3$, the load is lifted to a height equal to three times the space passed through by the piston; and when the water is allowed to escape from the cylinder A, through the pipe C C, by the opening of the passage in the box E, which communicates with a waste-pipe L, and the closing of that communicating with the main-pipe D, the piston returns towards its former position, and the load is lowered. The cylinder A, is placed in an inclined position, in order that the weight of the moveable carriage F, with its sheaves and appendages, may facilitate what is called the overhauling of the chain, by means of a counterweight K. For the purpose of causing the crane to turn round in either direction, also by the action of water, a cylinder M, is used. This cylinder contains a piston differing from that last described, in being acted upon by pressure on both its sides, and moves in either direction according to the side of the piston upon which the pressure of the water acts. The rod of this piston is connected with the rack N, which travels between guides, O O. The teeth of this rack work into corresponding teeth surrounding the lower margin of the collar P, to which collar P, and to the cap Q, the frame-work of the jib is fixed. R R, and S S, are the pipes by which the water under pressure is conveyed to or from the cylinder M, at either end, and the admission and emission of the water are regulated by a box slide-valve T. U V, are two valves, termed relief valves, and which are fixed on each of the pipes R R, and S S, of the cylinder M. The object of these relief valves is to prevent the circular motion of the jib being too suddenly arrested by the closing of the slide-valve in the box T, and will be better understood by reference to fig. 3, which is a sectional view of one of the relief valves U, representing a portion of one of the pipes or water-ways, S. *d*, is a small pipe communicating with the main supply pipe D, and *l* is a small pipe communicating with the waste-pipe L, and cistern W, which is kept charged by the waste-water from the cylinders A and M. In these relief valves there are clacks, each opening upwards, as seen at fig. 3, which shows the relief valve U, in section. S S, is part of one of the feed pipes leading from the slide-valve box T, to the cylinder M. *d*, is a small pipe leading from the top of the relief valve to the main supply pipe D, and *l* is a small pipe leading from the bottom of the relief valve to the waste pipe L and cistern W. The two clacks are lettered X and Y, and both open upwards. The manner in which these relief valves act, may be described as follows:—Suppose the jib of the crane to be swinging round by the action of the water upon the piston of the cylinder M, and suppose the pipe S, to be acting for the time being as the egress passage of the cylinder M, then, on the sudden closing of the slide-valve in the box T, the water on the egress side of the piston being deprived of its outlet, would suddenly stop the progress of the piston, and subject the whole turning apparatus to a violent shock, from the momentum of the jib, were it not for the clack X, which then gives vent to the confined water, and allows it to return into the main supply pipe D, as soon as the compression caused by the momentum of the jib becomes sufficient to raise the valve against the resistance of the weight of water operating on its upper side, and thus the piston, instead of being suddenly stopped, is only powerfully retarded, and the jib is brought to rest quickly, but without a shock.

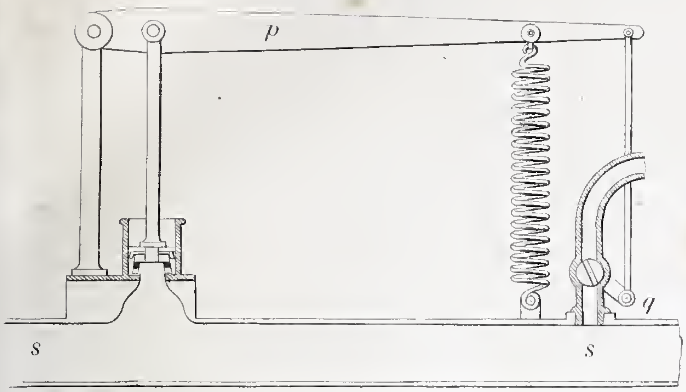
In the next place, if the pipe S, is acting as the ingress, instead of the egress passage of the cylinder M, then on the closing of the slide-valve in the box T, and while the momentum continues to impart motion to the piston, water would be sucked up through the clack Y, from the waste-water cistern W, to supply the void which would otherwise be left on the influx side of the piston. It will therefore be perceived that by applying a relief valve to each of the water ways R R, and S S, of the cylinder M, the detrimental effects which might otherwise result from the momentum of the jib, would be obviated in whatever direction the piston may be acting. At the same time the cylinder would be kept always fully charged with water on both sides of the piston, which would therefore receive an immediate impulse from the renewed pressure the instant the admission valve was re-opened.

Reverting to Fig. 1, Z is the index table, the internal arrangements of which are such that the operator turning the indices by means of a crank handle to each, has the entire control of the operation of the crane, the handle and index on the right, directing its revolving movements, and that on the left, its hoisting and lowering operations. The whole of the apparatus comprised in fig. 1, with the exception of the jib and pillar of the crane and index table, is placed underground, so as to avoid encumbering the surface, and the excavation in which the machinery is placed, is covered over with flags or boards.

In Plate IV., Fig. 1. represents a mode of arranging three cylinders for the purpose of obtaining various degrees of power for lifting or hauling by the power of water under pressure. When

# ARMSTRONG'S HYDRAULIC CRANE.

Fig. 5



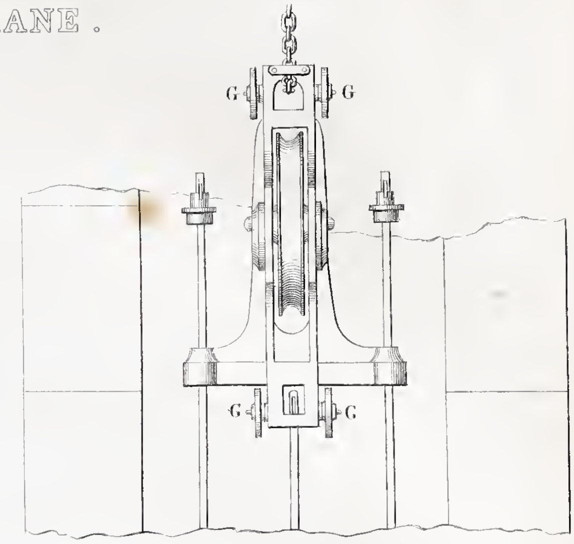




Fig. 1

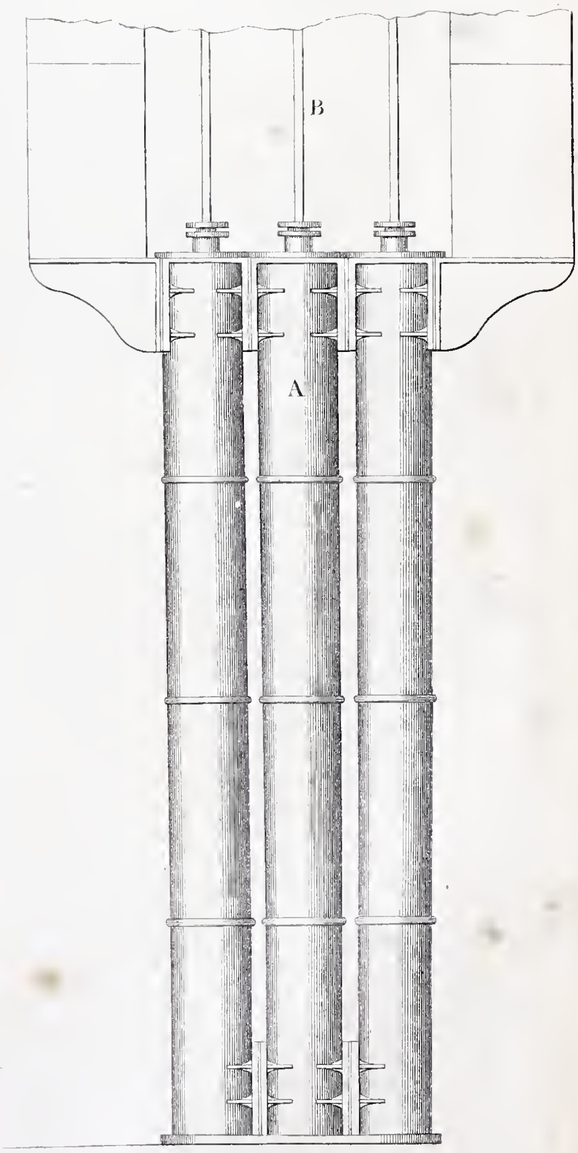
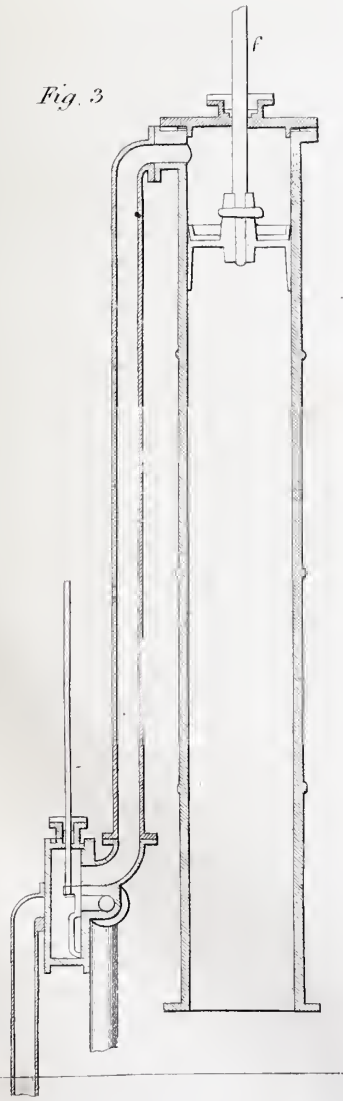
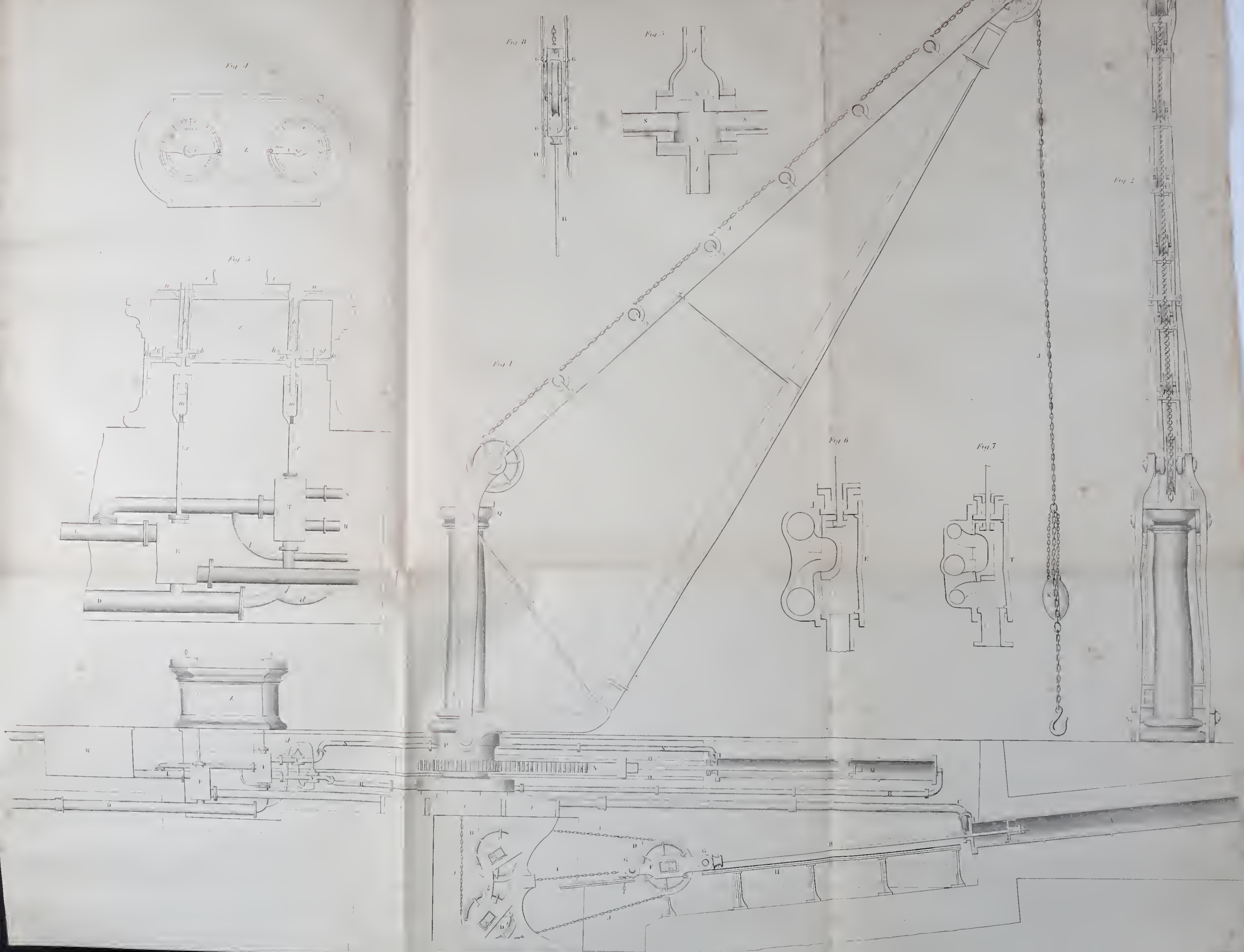



Fig. 3



A Beautiful Model of this Crane was Exhibited & obtained a Prize Medal at the Great Exhibition



Machines at the Exhibition



the lowest power only is required, the water is admitted into the centre cylinder alone: and while the travelling sheave is drawn along by the action of the middle piston-rod B, the two outer piston-rods (each of which is passed through a hole in the cross-head) remain at rest, the cross-head sliding over or along them. When the second power is required, then the water is to be admitted into the two outer cylinders, and shut off from the middle one, in which case the centre cylinder A, exerts no force upon the travelling sheave, but the piston-rods of the outer cylinders having stops or heads upon their extremities preventing their withdrawal from the holes in the cross-head attached to them, exert their combined force upon the cross-head, and upon the sheave connected with it, and merely carry the middle piston and rod with them; and lastly, when the power of all the three cylinders is required, the water is admitted simultaneously into all of them, and the three piston-rods then operate in concert upon the travelling sheave.

Fig. 3 is a sectional view of the vertical cylinder A. Fig. 4 is the top of the index table Z, drawn to a larger scale than that shown in Plate III.; and fig. 5 is the remainder of the apparatus connected with the index table, drawn to a similar scale. The crank-handle *i*, is fixed upon a rod *b*, which terminates at the lower end in a screw or spiral in the hollow head *m*, of the valve-rod *x*. The pointer *n* is fixed upon a tube which turns freely round the rod *b*, and carries a cogged-wheel *h*, fixed to the lower end of the rod *b*, which has also a small cogged-wheel or pinion *g*, fixed upon it; the pinion *g* works into a larger cogged-wheel *k*, carrying another pinion *j*, working into the larger cogged-wheel *h*, attached to the tube forming the axis of the pointer *n*, so that while the cranked handle *i*, makes a sufficient number of turns to move the slide-valve from one extremity of its range to the other, the space traversed by the pointer *n*, shall be confined within a single revolution.

Fig. 6 is a view of the slide-valve box E, shown in section, and drawn to a larger scale, and fig. 7 is a similar view of the slide-valve box T. Fig. 5 is a species of safety-valve, which may be placed upon the main supply D, to prevent its bursting by the sudden increase of pressure liable to take place in the pipe when the flow of water through it is from any cause abruptly stopped. The power of the water operating on the piston *r*, overcomes the resistance of a spiral spring attached to the lever *p*, and opens for a moment the escape-cock *q*, which relieves the strain upon the pipe.

## THEORY AND PRACTICE OF DYEING.

In furnishing a systematic outline of the principles and practical manipulations of dyeing, it may be expected that we should state the object we propose thereby to accomplish. This we believe is sufficiently well set forth in the general statement of the objects of this publication without any special reference to a particular class of workmen; and, we have only to repeat, that our business is to furnish materials of instruction for all. In reference to dyeing, it is unnecessary to state that it is essentially a progressive trade—a trade which is to be learned, and one, which, above all others, is dependent for its successful practice upon a knowledge of principles; and further, that those engaged in it are a body of workmen who have equal claims with any other to be furnished with information which may be conducive to their interests and the interests of their profession. The particular nature of the trade besides renders any information of this sort more needful, and therefore more valuable than ordinary. The trade is open so that any man may enter it; and in consequence, there are few instances where young men are put under a regular system of teaching, and trained to the business systematically. Those who become dyers, are moreover generally grown up, and their chief ambition is to learn the mechanical operations of the dye-house, and when sufficient dexterity in these is attained, along with the highest rate of wages to be got in the trade, zeal for improvement subsides. A few indeed there are, who not contented with the honours of a journeyman, aspire to a foreman's place; but the path by which they hope to climb to such preferment, is simply long and steady service, and a good memory for manipulation. Both of these are valuable qualifications, but they are qualifications which would not be depreciated in the slightest degree by being conjoined with a more extended knowledge of the fundamental principles of the art than usually falls to the share of the practical dyer. The amount of this knowledge is not only slight, but there is a palpable want of interest manifested in the dye-house in respect to everything beyond the mere mechanical operations, which is much and seriously to be lamented. Individuals who get to the position of good workmen value their abilities by the contrast which exists between them and the newly initiated journeyman; but they rarely or never look forward to the wide field which lies unexplored before them. Often indeed are they so unguarded as to boast aloud of their capabilities, of their expertness and their knowledge; and it is no uncommon thing to indulge in petty jealousy, and to endeavour to conceal the *secret* of their mode of working from their neighbours. Evils of this sort are not the workman's alone: it is no uncommon circumstance to hear an employer complaining that his men are inefficient workmen at the same time that he is stealing as it were from one part of the dye-house to another, with the very stuffs which it is their business to use, under a cover, lest any one should know what is the nature of the process by which he prepares some dye which he expects to be used advantageously by the very men whom he endeavours by all ingenious means to retain in ignorance of their trade. Under these circumstances it is no wonder that years are often spent—we should say wasted—endeavouring to discover what was long before known and patent to every one who knew the scientific principles of the art. It is the same ignorance of principles which renders both masters and workmen the dupes of those knaves who hawk about *valuable secrets* at so much a piece!

It must be admitted, however, that notwithstanding all untoward circumstances, the degree of advancement which the art has attained is truly astonishing. A single practical hint is sometimes sufficient to cause a complete revolution in some branch of the trade, so that were the principles of chemistry but once generally understood by those practically employed in their application to dyeing, we can hardly conceive what changes and improvements would be effected. We might instance the state of the trade among our continental neighbours, to whom we have been hitherto chiefly indebted for our improvements in the art; but this we believe is unnecessary; and it is surely unnecessary to suggest that British workmen, with better facilities and more practice, are as capable of becoming scientific dyers as Frenchmen or Germans.

The perpetual fluctuations of the trade which even in its best state, throws not less than a fourth part of the workmen idle during the winter months, is no doubt a serious evil. But while we admit the hardship of such a state of things in its fullest extent, we do not believe that this time should be allowed to glide by in absolute listlessness. It is still a portion of the allotted span of life, and ought to be turned to all the advantage which circumstances will admit; and if it can be made subservient to future advantage either by advancing the personal interests, or in augmenting the mental enjoyment of the individual, it is surely culpable to allow it to run to waste. We sincerely believe that it may be turned to account in both ways, and we promise with some confidence that the following chapters will suggest the means of drawing remuneration even from idle hours. Lord Bacon's maxim, that "knowledge is power," has been reiterated till it may be thought to have lost its virtue, but it is still as true as ever, and we are confident that it cannot be more truly applied than to the case of the practical dyer.

### CHAPTER I.

THEORY OF COLOURS—COLOURS OF THE VEGETABLE KINGDOM—ELEMENTS OF VEGETABLE SUBSTANCES—INFLUENCE OF LIGHT UPON VEGETABLES—APPLICATIONS TO DYEING.

There are, perhaps, no phenomena in nature, better calculated to arrest the attention and admiration of man, than the various colours of the vegetable kingdom; and to imitate nature in this profusion of beauty is and has been the pride of man in all ages, and in all ranks and conditions of life. The savage, with whom clothing forms no object of ambition, tattoos and daubs his body with all the various colours his ingenuity can prepare, while the civilized man, by a process more refined, imparts the colours to his clothing. From this passion of endeavouring to imitate nature in all that is beautiful, have sprung up the two kindred arts, dyeing and painting. Of the latter, the public have already the highest conceptions,—kings have taken it under their protection, and poets have sung its praises; but the former, though all enjoy its advantages, remains in comparative obscurity: it will

therefore be necessary, before offering any practical observations upon this branch of national industry, to point out some of the qualifications necessary for a dyer to possess, that the public may appreciate the talent necessary for the production of those beautiful colours which all vie to excel in.

Strictly speaking, colours have no material existence: it is altogether an optical delusion—at least they do not exist in the object which appears coloured, but in the light which is reflected from the apparently coloured object. A beam of light is composed of three differently coloured rays,—red, blue, and yellow; termed sometimes the *luminous calorific*, and the chemical rays from their different properties of giving out heat and light, or in exciting chemical action. When a beam of light strikes the surface of a body, it bounds off as an elastic ball would do striking the same surface, and this bounding off is termed reflection; or, it is absorbed by the body and disappears, and is altogether extinguished; or lastly, it passes through the body, making it transparent. In the first case, the bounding or reflected rays pass into the eye, and the body appears white, or some particular colour. In the second place, there can no light proceed from the object to the eye, it being absorbed and extinguished: the body therefore is invisible; or if the surrounding objects are illuminated, or reflect light, it appears black; and in the third place, the light passing through unaltered, the body appears clear. The less the light is altered, the more clear and transparent the body, and consequently the more nearly invisible.

We have already mentioned that light is composed of three differently coloured rays, namely, red, blue, and yellow, its whiteness depending upon the nice equilibrium of shade the one ray has to the other; but whenever by any means this equilibrium is disturbed, the light is no longer white, but some particular colour varying according to the rate of the disturbing influence. These different coloured rays are not reflected or absorbed in the same ratio when they fall upon the surface of bodies—hence the equilibrium is disturbed, and the result is a colour according to the difference in the reflection or absorption of the different ray or rays. If the red ray is absorbed, and only the blue and yellow rays reflected, the object from which they are reflected appears green; if the yellow ray is also absorbed, the object appears blue; or if it has been the blue ray that is absorbed, and red and yellow reflected, the object appears orange; or if the yellow ray only is absorbed, the object appears violet or purple. Thus, by the rate of the disturbing influence, and the different combinations of these three colours, are all the various shades in nature produced. From these observations it will be obvious, that the dyer, in order to understand the nature of his business, and to give the best possible effects to the various colours he produces, should be acquainted with the laws of light in relation to colours. But, were he to take this alone as his guide, he would find that in attempting to realize the results of the preceding theories, by mixing his colours accordingly, in some instances he would not succeed; as for instance, were he attempting to produce a white by immersing the goods in a mixture of red, yellow, and blue colour, he would get a brown—but this does not invalidate the law above stated, and in fact, the practice of producing white by the combining the three colours is had recourse to every day by the practical bleacher and dyer. All goods coming from the bleaching process, no matter what the nature of the process has been, have always a brownish yellow tinge: to cotton goods a little indigo or cobalt blue is added, and the result is, a much purer white: to silk, which has much more of the yellow tinge than cotton, a little Prussian blue and cochineal pink; or what is more common, a little archil, a lichen which grows on the borders of the Mediterranean, and which gives a violet colour, is added; the quantity varying according to the depth of yellow—the result is a beautiful white. The necessity of having a good white upon goods before being dyed, and the best means of obtaining this, will be given in another paper—our object in the mean time being to point out the laws upon which the theory of colours depends, and the necessity of practical men studying these laws. It may be asked, why all bodies do not transmit, absorb, or reflect, light equally, when they are placed under the same circumstances? This question cannot, as yet, be satisfactorily answered; and to enumerate the various hypotheses offered, would lead us from our purpose: it is sufficient to state, that so far as the production of colours is concerned, it depends upon the chemical constitution of the coloured body, and a peculiar arrangement of its atoms with regard to light. One or two simple experiments will serve to illustrate this. Take a solution of iodide of potassium, which is colourless and transparent, and divide it into three proportions: into the one pour a little acetate of lead (sugar of lead); into the other a persalt of mercury; and into the third a little starch with a few drops of nitric acid. These are all colourless substances; but after they are mixed, in the first we have a deep and beautiful yellow; in the second a red; and in the third a blue; thus we have the three primitive colours, produced by the same substance combining with other substances all previously colourless: no other explanation can be given for the production of these colours, than the peculiar arrangement of the particles with regard to light. Many white flowers, when maccrated in water, give the water a yellow colour, which alkalies, such as potash, and soda, turn green.

Seeing then that colours depend upon the chemical constitution of the body, a dyer ought also to be a chemist, acquainted with the different substances which enter into the composition of bodies, and the laws which regulate their combining together.

We have here pointed out some of the qualifications of a dyer, but have reason to regret that these qualifications have been much neglected. Chemistry has got far ahead, and in many instances can scarcely be identified in his processes—while obsolete theories cling most tenaciously to him. Scientific chemistry is also much retarded by his neglect. Who is better qualified to advance a science which depends wholly upon experiment, than the man whose daily avocations are a continued round of experiments?—and yet the dyer, for the want of a little observation, and not taking advantage of the inductions of scientific men, is comparatively ignorant of chemistry; and the theoretical man, for want of the dyer's experience, comes to hasty and erroneous conclusions, or overlooks the niceties requisite for a successful dyeing experiment. In proof of this, I shall cite two instances:—" Concentrated nitric acid acts very strongly upon iron filings, much nitrous gas is disengaged at the same time. The solution is of a reddish brown colour, and deposits the oxide of iron. After a certain time, more especially if the vessel be left exposed to the air, a diluted nitric acid affords a more permanent solution of iron, of a greenish colour, or sometimes of a yellow colour. *Neither of the solutions affords crystals.*"* Now, long before this paragraph was written, the dyers, who use this salt in great quantities, were often annoyed by it crystallizing. The other is from a little work well adapted for a beginner.† "Add to a solution of sulphate of indigo an equal quantity of carbonate of potash; a piece of yellow cloth dipped into this will be changed to green, and a piece of blue litmus paper to red." Now, every dyer, who knows anything of this process, knows that if the sulphate of indigo would turn blue litmus red, it would not die a yellow piece green; for the acid which turned the litmus red would *strip off*, as dyers term it, the yellow: hence, instead of a green would result a dirty blue, which could not be dried without injuring the cloth, and if previously washed, the colour would disappear. Now a dyer, meeting such statements, generally comes to a wrong conclusion: reasoning from analogy, he sets aside the valuable researches of these authors, because they have been unable to describe the practical details of dyeing a particular colour, which none but a practical dyer is able to do. But such evils will continue, so long as the practical and the theoretical man remain two persons.

We shall now turn to the consideration of the chemical changes which are supposed to take place in nature, giving rise to the various colours presented to us in the vegetable kingdom, which will probably aid us in describing the artificial means of imitating nature in these colours, although as yet there is comparatively little known concerning the nature of these changes. For a long time, chemists considered iron to be the colouring principle of all animals and vegetables, being almost universally diffused, and capable of assuming a variety of colours either as oxides or solutions; but it was afterwards demonstrated that the iron present in any vegetable, even in those where it existed most abundantly, was altogether inadequate to produce the splendid colours which vegetables assume. Several other hypotheses were proposed to account for the colours of vegetables; but these hypotheses, not being founded upon inquiry and proof, died at their birth. It is only within these few years that

* Ure's Dictionary of Chemistry.
† Griffin's Chemical Recreations.

the true method of ascertaining the nature and cause of vegetable colours has been adopted; that is, by the ultimate analysis of vegetable substances in all the stages of existence; and since then, a number of important facts have been made known respecting this interesting subject, and new ones are daily being added; and we hope that these discoveries will be speedily made available by the practical man.

The principal elements of vegetable substances are, oxygen, hydrogen, carbon, and nitrogen: the last exists in such a minute quantity, that in many cases it is scarcely appreciable; but according to the opinion of Liebig, who stands at the head of this department of chemistry, it is never absent. There is also a variety of earthy substances in vegetables, such as lime, iron, magnesia, soda, potash, &c.; but, all these never exist in one vegetable—some of them seem indispensable for the existence of a plant; but they differ according to the nature of the plant, and the soil on which it grows. The three elements, oxygen, hydrogen, and carbon, enter very abundantly into the composition of vegetables, forming from 95 to 99 per cent.; but it must not be supposed from this, that all vegetables are alike in their chemical properties—they may be as varied as those substances which constitute the mineral kingdom. This depends upon a well-known law in chemistry, termed the law of definite proportions; that is, every compound substance has a particular number of elements, and a definite number of each element. The following table, showing the composition of a few compounds which constitute a great mass of all vegetables, will serve to illustrate this.

| | Carbon. | Hydrogen. | Oxygen. |
|---|---|---|---|
| Woody fibre, . | 15 | 10 | 10 |
| Gum, . . | 12 | 11 | 11 |
| Starch, . . | 12 | 10 | 10 |
| Sugar, . . | 12 | 11 | 11 |

It will be observed from the above table, how little is necessary to produce an entire different compound. It will also be observed, that gum and sugar are the same: this appears an exception to the law above described. Those bodies which have their elements in the same proportion, are termed *isomeric*, signifying *equal parts*. The discovery of bodies having the same number of elements, and differing in their chemical properties, excited much interest among *chemists*, and has led to much careful study and investigation; and the result has been rather unfavourable to the doctrine of isomerism: they are substances which our neighbours on the other side of the water would designate the *same* with a *difference*—the difference is supposed to be in the numerical arrangement of the elements. As for example, hydrogen and carbon will combine in the proportion of two and two, four and four, and eight and eight, forming three substances, differing considerably in chemical properties, although the elements are combined in the same proportion; but, interesting as this subject is, we cannot in the mean time enter into any lengthened details—it shows us however the extensive means employed by nature for giving variety of substances. Another thing to be observed from the above table is, that the oxygen and hydrogen in each of these compounds are in the same proportion, or in that relative proportion in which they unite to form water. Now, it may be stated as a general rule, that when oxygen and hydrogen are united to carbon, in the proportion in which they form water, the resulting compounds are of a saccharine or mucilaginous character.

When vegetable compounds have hydrogen united to carbon without oxygen, or when there is less of that element than would be required to convert the hydrogen into water, the resulting compounds are generally oily, resinous, or alcoholic. A table of the composition of a few of these substances will illustrate this:—

| | Carbon. | Hydrogen. | Oxygen. |
|---|---|---|---|
| Oil of turpentine, . | 10 | 8 | |
| Oil of potatoes, . | 5 | 6 | 1 |
| Oil of cloves, . . | 23 | 14 | 5 |
| Resin of gamboge, . | 20 | 14 | 5 |
| Caoutchouc, . . | 4 | 4 | |
| Bees' wax, . . | 37 | 39 | 2 |
| Pyroxilic spirit, . | 2 | 4 | 2 |
| Alcohol, . . . | 2 | 3 | 1 |

When the proportion of oxygen united to carbon is in greater quantity than the hydrogen, or when none of this element is present, the resulting compounds have generally an acid character: green fruits are in this state, which gives them the sour taste, and makes them deleterious to health, either by giving too much acid to the stomach, or the acid being of a direct poisonous nature; but as the fruit ripens, it takes in or assimilates more hydrogen, and the acid, or at least part of the acid, is converted into a saccharine compound. The following table will show the composition of a few of the most common acids found in vegetables:—

| | Carbon. | Oxygen. | Hydrogen. |
|---|---|---|---|
| Acetic acid (vinegar), . | 4 | 3 | 3 |
| Tartaric acid, . . . | 4 | 5 | 2 |
| Citric acid (lemon juice), | 4 | 4 | 2 |
| Gallic acid, . . . | 7 | 5 | 3 |
| Tannic acid, . . . | 18 | 12 | 8 |

There are also a number of vegetable alkalies which are found united to acids in plants, which, however, need not be specially noticed here, further than that they almost all contain nitrogen as an ingredient. There are other substances in which nitrogen enters into their composition, and which are useful in the production of colours by art, but which will be noticed under their respective heads.

Having given an outline of the nature and composition of the principal vegetable compounds, we shall now inquire into the cause of their assuming certain colours, and the effects which acids have upon these colours.

At the commencement of this article, we mentioned that colours depended wholly upon the reflection and absorption of light, by the apparently coloured substance; but it was also mentioned, that this result depended upon the chemical constitution of the particular substance; hence, the inquiry into the cause of vegetable colours becomes a chemical one; and, from the chemical laws above described, these colours must have a definite constitution; and when any change of colour takes place, there must also be a change of chemical constitution. In prosecuting this inquiry, or rather, in collecting the inquiries of the most eminent chemists upon this subject, we shall begin with the paramount colour of the vegetable kingdom, namely, green.

Green is well known to be a compound colour, produced by yellow and blue, and is always induced upon cloth by dyeing it first the one and then the other. It is not always the yellow that is dyed first, according to the description in chemical books; but sometimes the blue, according to the nature of the dyeing agent, which will be explained in its proper place. Speaking of vegetable green, Berthollet says, "the green of plants is undoubtedly produced by a homogenous substance, in the same way as the greater number of hues which exist in nature. This colour owes, then, its origin sometimes to simple rays, and sometimes to a union of different rays; and some other colours are in the same predicament. Were the green of plants due to two substances, one of which is yellow and the other blue, it would be extraordinary if we could not separate them, or at least change their proportions by some solvent." This idea of Berthollet, that the green of plants is a distinct substance, existing in the plant, has been since verified. It is obtained by bruising green leaves into a pulp with water, pressing out all the liquid, and boiling the dry pulp in alcohol: when the alcohol is evaporated, there remains a deep green matter, which, by digesting in water, dissolves, and frees it from a little brown colouring matter, with which it was mixed. This substance has been named chlorophyllite. The formation of chlorophyllite seems to depend entirely upon the action of the solar rays. "It is known that the function of the leaves and other green parts of plants is to absorb carbonic acid, and, with the aid of light and moisture, to appropriate its carbon. These processes are continually in operation: they commence with the formation of the leaves, and do not cease with their perfect development." But when light is absent, or, during the night, the decomposition of carbonic acid does not proceed; nay, carbonic acid is emitted, and oxygen gas absorbed: it is evident then that a plant kept always excluded from the light, must have a difference in its composition. "No one can have failed to observe the difference between vegetables thriving in the full enjoyment of light, and those which grow in obscure situations, or which are entirely deprived of its agency: the former are of brilliant tints; the latter dingy and white. Numerous familiar instances might be cited, especially among our esculent vegetables: the shoots of a potato produced in a dark cellar are white, straggling, and differently

formed from those which the plant exhibits under its usual circumstances of growth. Celery is cultivated for the table by carefully excluding the influence of light upon its stem: this is effected by heaping the soil upon it, so as entirely to screen it from the solar rays; but if suffered to grow in the ordinary way, it soon alters its aspect, throws out abundant shoots and leaves, and, instead of remaining white and of little taste, acquires a deep green colour, and a peculiarly bitter and nauseous flavour. The heart of the common cabbage is another illustration, and the rosy-coloured aspect of the sides of fruit is referrible to the same cause. Changes yet more remarkable have been discovered in plants vegetating entirely out of the access of light. In visiting a coal-pit, Professor Robinson found a plant with a large white foliage, the form and appearance of which were quite new to him: it was left at the mouth of the pit, when the subterranean leaves died away, and common tansy sprung from the roots."*

From those facts we see that the green colour of vegetables is owing to a peculiar approximate element existing in the vegetable, not invariably, nor altogether essential to the plant, but depending upon circumstances; those circumstances being at the same time the best for the health and existence of the plant. This colour differs from the other colours of vegetables in the time of its appearing. Flowers of plants do not appear till the plant has reached a certain state of maturity; but whenever a plant rises above the soil, it immediately begins to assume the green hue, and this hue is continued till the object of the leaves is completed. When a *chemical change takes place*, the green passes away, and another colour, reddish-yellow, takes its place. These changes are effected in different degrees, and in different lengths of time, just according as the leaves have the property of absorbing oxygen gas. Those leaves which continue longest green absorb oxygen slowest. The leaves of the holly will only absorb a small fraction of oxygen, in the same time that the leaves of the poplar and beech will absorb eight or nine times their bulk. These last are remarkable for the rapidity and ease with which the colour of their leaves changes. That leaves do absorb oxygen gas when they change colour at autumn, and that it is owing to the absorption of this gas, may be verified by placing some green leaves of the poplar, the beech, and the holly, under the receiver of an air-pump, and drying them thoroughly, keeping them excluded from light; when taken out, wet them with water, and place them immediately under a glass globe, full of oxygen gas, they will change colour; and it will be found that each will change colour just in proportion to the quantity of oxygen it absorbs. The consequence of this absorption is the formation of an acid, in accordance with the law mentioned in a former part of this paper. This acid changes the chlorophyllite, or green principle, from green to yellow, and then to a reddish hue. If we treat green leaves with an acid, the same changes of colour take place, and if we macerate a red leaf in potash it becomes green.

The various and beautiful colours of flowers are produced by a somewhat different process from that of the green of the leaves, in so far as they do not appear until the plant has attained a certain state of maturity. "The leaves of the plant being fully developed, they take in more nourishment from the atmosphere than what is necessary for the existence of the plant. This extra nourishment takes a new direction; a peculiar transformation takes place; new compounds are formed, which furnish constituents of the blossoms, fruit, and seed."†

It is very probable that all the colours of flowers depend upon only a few approximate elements formed in the vegetable, in the manner already described, and that their various hues are the consequence of the presence of acids affecting more or less this colouring substance. This is the most probable hypothesis that has been formed, and with which we must rest satisfied till more accurate experiments verify its truth, or give us a better. The following summary of experiments will give some idea of the views held upon this subject:—"The expressed juice of most red flowers is blue; hence it is probable that the colouring matter in the flower is reddened by an acid, which makes it escape when the juice is exposed to the air. The violet is well known to be coloured by a blue matter, which acids change to red; and alkalies and their carbonates, first to green, and then to yellow. The colouring matter of the violet exists in the petals of red clover, the red tips of the common daisy of the field, of the blue hyacinth, the hollyhock, lavender, in the inner leaves of the artichoke, and numerous other flowers. The same substance made red by an acid, colours the skin of several plums; probably, also, gives the red colour to the petals of the scarlet geranium, and of the pomegranate tree. The leaves of the red cabbage, and the rind of the long radish, are also coloured by this principle. It is remarkable that those, on being merely bruised, become blue, and give a blue infusion with water. It is probable that the reddening acid in those cases is the carbonic, which, on the rupture of the vessel which encloses it, (being a gas,) escapes into the atmosphere. If the petals of the red rose be triturated with a little water and chalk, a blue liquid is obtained. Alkalies render this blue liquid green, and acids restore its red colour."

* Brand's Chemistry. † Liebig's Agricultural Chemistry.

## IRON-FOUNDING.—SECTION I.

*First Remarks.*—The general object of iron-founding is, to mould iron in a melted state into the various forms required for the parts of machines and other constructions. Wrought iron and steel cannot be properly melted by heat. At high temperatures, they drop away and spark off, while the main body of the metal maintains its consistency, and it undergoes rapid oxidation, as is shown by the scales which are perpetually formed on the surface. Those metals are, however, in this condition rendered extremely ductile, and the wrought iron especially may be fashioned with facility into any required form by the application of the hammer. On the contrary, pig iron, of which wrought iron and steel are preparations, has peculiarly the property of liquefaction by heat, and is therefore well adapted as a material for castings, in which strength and hardness are required.

The business of the iron-founder is therefore to take advantage of the common law, according to which fluids always find their level. If, for example, a quantity of water be poured into a vessel, however curiously shaped, it first finds the bottom, and then spreads on all sides as it rises, filling every corner it can reach. The body of water must then be a perfect model in form of the interior of the vessel, and this may be seen by solidifying it in its place by the application of cold, and extracting the body of ice.

To mould a quantity of melted iron into any desired form, two things are therefore necessary; first, a model or pattern of the required form; secondly, a substance of sufficient susceptibility and adhesiveness, to receive accurately, and to retain impressions of that pattern made upon it, against the violence of the liquid iron, when run into the mould which is thereby formed.

*Of Patterns.*—As to the material of patterns, wood is almost universally employed—yellow pine and mahogany being the kinds principally used. Of these, yellow pine is in by far the most common use. It is very suitable, being very uniform in substance, little interrupted with knots, sufficiently hard, works cleanly and with ease, and, moreover, there is plenty of it. Mahogany does excellently for small patterns, but its expense limits its application to the construction of those. It can be cut very clean, and its superior density and closeness of grain render it well fitted for nice patterns, such as of bushes for journals, small pinions, the teeth of wheels below 1 in. pitch, and in every case of a similar nature, in which the fibres of the wood may be presented endwise to the surface; whereas in working fir in this manner for minute purposes, it is apt to be broken away at the edges.

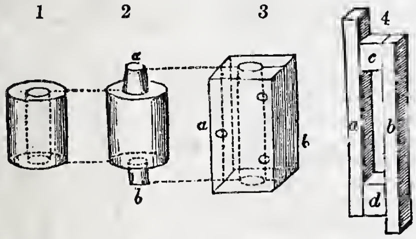
Plane-tree, beech, and red-pine are seldom used. Plane-tree has a very fine and agreeable tissue, and is very suitable for sharp, well-defined patterns, and small patterns intended for constant use, as it retains its sharpness for a long time. Red pine is remarkable for its toughness and straitness of grain, but it is coarse in the fibre. It is only employed for pinning together pieces of wood of deficient dimensions. It does well for purposes of this sort. White pine was formerly much used for patterns, but it has long been almost entirely dismissed as a material for such a purpose, on account of the roughness of its cross-cut.

After an original wood pattern is made, for purposes of ligh flat moulding, an iron pattern is cast off it, from which afterwards all the moulds are made, as the iron one lasts longer by a great deal than the other, and will preserve its form, which

in a wooden one is liable to alter in the course of time, especially if the pattern be slender, and the material not thoroughly dry. Tin is frequently used instead of iron, chiefly for patterns of ornamental work, as it can much more readily be cleaned up and smoothed for service. To preserve wood patterns from the effects of damp, a coat of paint ought to be given them, and this is very serviceable in moulding the patterns of wheels, for even during the time of being amongst the sand, which is always damp, the teeth, especially those of smaller pitch, are liable to swell, and have their form destroyed. And as patterns are frequently made of wood not thoroughly dry, they shrink afterwards as they become drier; and those especially which have great extent in proportion to their thickness, such as patterns for plates, will twist at right angles to the direction of the grain, in consequence of the unequal shrinking of the opposite sides. To prevent them from altering their form, bars of wood are nailed across them, which of course leave their impressions in the sand; and it is the care of the moulder to fill these up.

*Use of Patterns.*—The construction of patterns requires from their nature in many cases to be modified, so as to render the moulding of them practicable. For example, for castings in which recesses or holes passing quite through them are wanted, it is easy to see that were the space, in many cases actually made in the pattern, to be afterwards occupied by the sand of the moulding, it would carry off the *core* of sand as it is called, altogether. The making of these holes must be provided for in another way. Distinct cores are made by other means, having exactly the dimensions of the hole required in the casting, and that they may be securely held in their positions in the moulding, their ends project into counterpart holes in the sand, and are there fixed. These holes are formed by corresponding projections made in the pattern, named *core-prints*. For example, were it required to cast a coupling for shafts, of a cylindrical form, 12 inches deep, by 8 inches diameter outside, and 4 inside diameter, as sketched (fig. 1), a pattern of the same size, (fig. 2) is made,

1 2 3 4




and two prints *a*, *b*, are put on, in the proper positions to support the core; this is made of sand in a *box*, shown by fig. 3, which is simply two thick pieces of wood, *a*, *b*, held together by wooden pins. Into each of these, half the core hole is cut, so that when the core is formed in it, it may easily be got out by separating the halves. If then after the pattern (2) has been moulded, the core formed in the box (3) be inserted in the recesses left for it by the prints, the casting (1) will be formed, which otherwise would have been solid; for, were a pattern made like fig. 1, with the hole made through it, on withdrawing it from the sand, it would most likely carry off the *core* with it. In this instance, indeed, with much care on the part of the moulder, he might have managed to leave the core in its position unbroken, on account of its considerable diameter; but if it had been much smaller, say 2 inches, it could not have stood the tug of the pattern, and much less the shock of the melted iron. But, further, it is quite impracticable when the core lies horizontally, as the pattern in being withdrawn would, of course, unavoidably lift it away.

Thus, by means of distinct cores formed by boxes, holes and recesses of every kind are made in castings, if they be not already formed in the pattern.

Square cores are formed by two slips of wood, *a*, *b*, fig. 4, of the required thickness, and kept apart at the ends, by two pieces *c*, *d*, forming, by filling the space within with sand, the core required. It is, however, foreign to our present purpose to describe the construction of patterns, further than is necessary to the elucidation of the subject under consideration.

*Materials used in Moulding.*—The principal materials used n the various branches of moulding are, sand of various kinds, clay, blackening, coal-dust, and cow-hair

Sand is superior to all other substances as a material for forming moulds generally. For, in the first place, the hot iron has no chemical action upon it, though certainly it acts upon the matters which it is found necessary to associate with it, namely, blackening and coal. But secondly, it operates well as a conducting medium for the air expelled from the space filled by the iron, and for the other gases generated by the action of the heat on the blackening and the coal. And thirdly, it possesses considerable adhesiveness when rammed together—sufficient indeed, to make it retain its form against the pressure of the melted iron; and, moreover, it is easily made to conform itself very accurately to the surface of the pattern imbedded in it.

The sand of the London basin is the finest in the country. It is universally employed in the manufacture of fine goods, as grates, fenders, and the like. The sand in the neighbourhood of Falkirk is coarser and opener in the pores, which unfits it for such work. It is employed for casting hollow ware—pots and kettles, for example, as the enclosed air escapes freely through the inside body of sand in the moulding of such articles. It affords a beautiful smooth skin to the castings from Scotch iron, so remarkable in the hollow goods of the Carron Iron Works in Stirlingshire, and of the Phoenix Iron Works at Glasgow. The Belfast sand is finer than that from Falkirk, and is used principally for fine machinery castings. It is also sometimes used for facing the moulds of ornamental work, to give a fine surface. It is besides excellent for hollow moulding, when mixed with the Falkirk sand; but it is too expensive for general adoption in that way. It is a mixture of a very fine adhesive sand, and an opener kind. Rock-sand, the debris of abraded rock, and free-sand from the sea-shore are employed for making cores. The former, by itself, does very well for short cores, which open into the sand of the mouldings at both ends, as it contains a proportion of clay in its composition, which gives it cohesion. But it requires to be moderated with free-sand, to make it opener for the better escape of the air in its pores, when used for cores of considerable length, which of course are surrounded on all sides by the iron, except at the small portions at the extremities, by which alone the air can find exit. Free sand is also used alone for such cores, but as it wants adhesiveness, it requires to be tempered with clay water, barm, or the refuse of pease meal. In the use of the last, accuracy is required in proportioning it. The first is used in ordinary cases, and the barm only in very particular cases.

Clay is also very much employed, when mixed with sand, for loam-moulding. These ingredients are ground together with water, to give them consistency, and their proportions generally are one part of clay to eight or nine parts of sand. This, with a handful of hair mixed with it, forms ordinary *loam;* and a shovelful of horse-dung, seeds, or saw-dust, is added for *core-loam.* The purposes of these minor elements will be afterwards referred to.

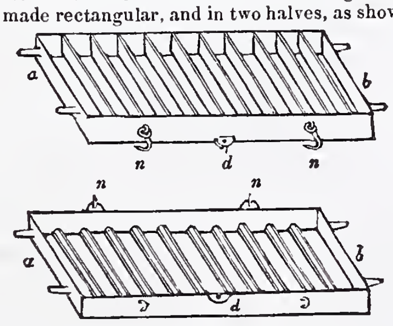
Blackening and coal-dust are employed to resist the penetrating action of the iron on the sand. Blackening is simply charred oak wood ground to powder. Oak charcoal is superior to all the other ordinary wood charcoals for the purpose, as it is the heaviest. Other wood charcoals are apt to be disengaged from the surface of the mould to which they are applied, and to float in the iron while liquid, which of course defeats the object of their use. According to Mr Mushet's experiments, oak produces 22·6 per cent., that is, fully one-fifth of its weight of charcoal. Were the iron allowed to come into direct contact with the sand of the mould, it would enter its minute interstices, and thus yield but a rough surface. To avoid this, blackening is dusted over the surface of the mould, pressed down on it, and smoothed, in cases of green sand castings, but it is mixed with clay-water, for covering loam-mouldings. Its essential property as a protector of the sand, is its inflammability. All combustible solid substances peculiarly resist liquid iron, as may be exemplified in pouring in over a smooth surface of wood. It rolls about as lively as mercury, on account of the continued effusion of gaseous matter by the combustion of the wood heaving up the iron from the surface. Now, in cases of heavy castings in green sand, as the action of the metal becomes too powerful for the blackening, this is assisted by coal-dust, which is mixed uniformly in the sand. It is never more than one-tenth of the sand in bulk, and the best kind of coal for the purpose, is the rich hard splint coal.

*Kinds of Moulding.*—The art of moulding may be divided into two great divisions; namely, green and dry-sand moulding, and loam-moulding. In the first division, patterns of the articles

wanted are universally employed in forming the mould; in the second division, the ordinary patterns are dispensed with, the objects of this division being heavy castings of a regular form; as cylindrical bodies generally, and other circular ware, such as sugar-pans, and gas-retorts. Large square vessels, water-tanks, for example, may also be made by a process of loam-moulding. The first division again embraces every other variety of article, for which there must be patterns. Dry-sand moulding is generally employed for the making of pipes, columns, shafts, and other long bodies of a cylindrical form. It is firmer and better adapted to purposes of this kind than green sand. The material of dry sand, is the loam already used in loam-moulding, called *pit-sand* mixed in the mill with an addition of rock-sand. It is named dry sand, in contradistinction to green sand, because, after being moulded, it must be dried by heat to fit it for the purpose; whereas the latter is employed as it comes from its native bed, new and damp; the dampness indeed is assisted afterwards when necessary, as a certain degree of it is always requisite.

The operations of green-sand moulding are generally recognised under two great classes—hollow moulding, and flat moulding. The former includes pots, frying-pans, and every other kind of cooking ware, of a light dished form. The latter class is very extensive, and is so termed in opposition to hollow-moulding. It includes all objects of a flat nature, the various parts of grate furniture, for example, and other ornamental work generally, stoves, roans, smoothing-irons, all kinds of machinery that do not fall under loam and dry-sand moulding, for instance, all the cast-iron work of spinning and loom machinery. In fact, a kind of subdivision exists, known as job-moulding—a homely term, including machinery generally, and the heavier kind of work, distinguishing them from the ornamental and the other lighter work. A steam-engine affords in the parts of it, examples of the three kinds of moulding. The steam-cylinder and the air-pump which are round, and the condenser, which is often square, are instances of loam-castings,—the fly-wheel shaft, and the single columns supporting the framing are examples of dry-sand castings, and the beam, sole-plate, entablature, and connecting rod, if of cast iron, are referrible to the heavier green-sand casting. The cistern plates, too, are decided instances of flat moulding.

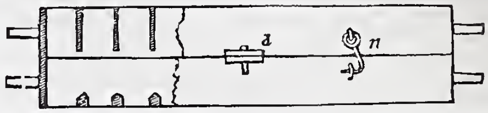
*Processes and Tools.*—The processes of green-sand moulding and the tools employed in it, claim our first attention. In processes of green and dry-sand moulding, boxes are always employed, the purpose of which is, to contain the sand in which the pattern is moulded. These boxes are for convenience of various sizes. If there be a great, or constant demand for castings of one form, boxes are made expressly for them, corresponding in form. By this plan, a saving of labour is effected, as the ramming up of useless corners with sand is avoided. For general purposes, boxes are made rectangular, and in two halves, as shown in the sketch annexed. These boxes have neither top nor bottom, but each half-box, or more correctly each box, is composed of an outside rectangular frame *a b*, which is generally 3, 4, or 5 inches deep for the lighter flat-moulding. They




have transverse ribs joining the opposite sides at equal distances of $4\frac{1}{2}$ inches between them. The object of their being open on the upper and under sides is, to allow the application of the tools for ramming the sand in the box; the ribs being at the same time sufficient as holding surfaces for the sand, which is formed into a close adhesive mass by the ramming, and in a manner dovetailed into the ribs. The rougher, therefore, these boxes can be made, the better—they hold the sand more effectually, and accordingly in casting the boxes themselves, the patterns for them are simply laid in the sand on the ground, and after being rammed, are drawn out. There is no blackening used for the surfaces of the moulding, and thus the iron enters the pores of the sand, and roughens.

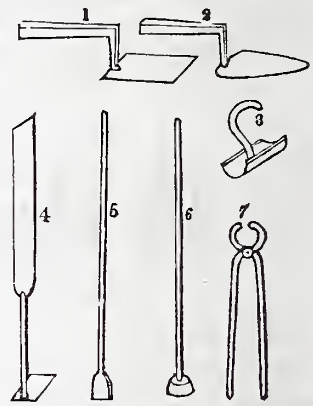
As there is no covering for the mould, it being exposed to the air, this mode of casting is named open-sand casting. The exposed surface is made, however, very irregular and rough, so that this mode of casting is used only for moulding boxes, when the roughness is a virtue, and for articles of a coarse nature.

The figure annexed is a longitudinal view and partial section of a pair of boxes, in which it is seen that the ribs of the upper




box are not so deep as the outside frame. They are generally an inch less deep to allow a depth of sand over the pattern that is imbedded in the sand of the lower box. The frame of this box, called the drag-box, is the same as that of the upper, but the ribs are much shorter and thicker, as it is not required to be moved about and inverted like the upper one; besides, it allows much more available depth of space for the moulding of the pattern. As the lifting and shifting of these boxes, when small, is usually managed by two men, they have two snugs or handles at each end, seen in the first figure, by which they are held. They have also usually three hooks and eyes, *n*, *n*, and three pins and holes to receive them, arranged alternately along the sides, there being two on either side, and one over the other. The pins are fixed on ears, *d*, *d*, *d*, cast on the sides of the drag box, and pass through holes made in ears on the upper box, which correspond, so that the boxes in being placed and replaced together, must have always the same relative position. The hooks and eyes hold them tightly together for the casting.

The sketches annexed represent the different kinds of tools employed by flat-moulders in the execution of thin work. No. 1, is the trowel—the instrument in most frequent use by moulders. There are various sizes of it used, from $\frac{1}{4}$th to 2 inches broad in the blade, and 3 inches long generally. The purpose of the trowel is to clean away and smooth down the surface of the sand, to press down and polish the blackening, repair injured parts of the moulding, and so on. No. 2, is another form of trowel of a heart-shape. It is particularly employed for

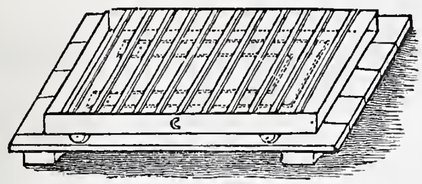



entering acute angles in a moulding, into which the square trowel evidently cannot go. No. 3, is another form of tools for managing hollow impressions in the sand. No. 4, is the form of the sleeker and cleaner. As the trowel is applicable only to open plain surfaces, this tool is used for cleaning and smoothing sunk surfaces in the sand which the ordinary trowel cannot reach—as the impression of a flange, or of any flat part of a pattern presented edgewise to the sand. The upper end is applied to the sides of such an impression for sleeking or smoothing it, and the under end goes to the bottom, where it is used both for taking up loose sand lying there, and for pressing and smoothing down the surface. It is to be noticed too, that the upper end is presented edgewise to the direction of the *spade* at the under end, so that when this is employed at the bottom of a deep recess, the upper end stands sideways to the side of the recess and permits free motion. No. 5, is the first rammer; it is about 4 feet 6 inches long, and its under face is about 2 inches $\times$ 1 inch. Sometimes the upper end, by being tapered off, is made to serve for forcing holes in the sand. No. 6, is the second rammer for finishing the work of the first. It is round in the face, about $3\frac{1}{2}$ inches diameter, with a wooden shank of convenient length. No. 7, represents the pincers used for laying hold of and shifting about the castings. They have no peculiarity except in having their holding faces round and flat.

Besides these tools, shovels are used for working the sand, sieves and riddles for refining it, and bellows for blowing off loose sand from mouldings; pots for holding the parting sand

and the water used in moulding, swabs for applying this water to the mouldings, being simply tufts of tow brought to a point, and separate linen bags of pease-meal and blackening, through the texture of which these materials are shaken on the sand. There are also piercers or "prickers," as they are named, being pieces of thick iron wire sharpened at one end to a point, for piercing the sand to let off air.

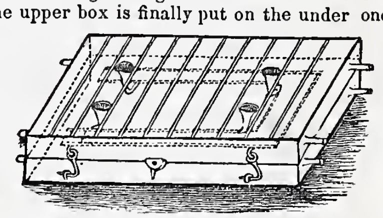
*Process of Moulding in Green Sand.*—Take, for example, the front of a register grate, which is a familiar instance of light flat moulding. Its construction is that of two jambs joined at the top by a cross piece. On the back, or inner surface, it is quite flat, and is ordinarily ornamented on the face with raised figures of flowers, &c. A box is selected that will receive the pattern and have a few inches to spare, that the pattern may be completely surrounded with sand. The pattern is then laid down either on the surface of a bed of sand, prepared in the upper box, which is lying inverted on the ground, or on a flat board of sufficient size to support it at all parts. In either case the pattern is laid down on its back; there is next thrown over this a layer of fine sand of an inch deep, constituting the facing of the moulding. It is passed through a sieve to detain the coarser parts. Then, upon the board or upper box, which we shall call A, the drag-box, B, is placed in its proper position in respect to the pattern. The annexed figure shows how things now stand.



It is necessary to spread the facing of sand before laying down the box, as its ribs prevent the equal distribution of the sand over the pattern. Then a larger quantity of sand is passed through a riddle which saves the small stones and other refuse in the sand. An additional quantity of the common sand is thrown in by a shovel, and the whole is now rammed down by the flat rammer as equally as possible. This is facilitated by a considerable depth of sand having been laid on, as inequalities in the force of ramming are diminished at the surface of the pattern. The box is again filled up with sand and rammed all over with the round-faced instrument. When the sand is properly set, and squared flush at the surface with the box, B, the whole is turned over, (avoiding sudden shocks of any kind, which tend to loosen the sand) and well bedded on the ground with the box B undermost. The box A, or the board, as it may happen to be used, is lifted off, and the temporary bed of sand in the box A is destroyed. The upper surfaces of the sand in the box B, and of the pattern imbedded in it, are cleaned and smoothed by the trowel, so that the surface of the sand is made flush with that of the pattern all round, and also meets the edges of the box. This forms the *parting*, or place of separation of the sand in the two boxes; and that they may afterwards separate properly, dry sea-sand is sprinkled over the parting surface, and has the effect of preventing the adhesion of the sand to what is afterwards superimposed, by entering and drying its pores. The box A is now laid on the other, guided by the pins, and both are fastened together by the hooks. In bringing them together their meeting surfaces ought to be cleared of sand so as to make them bear freely and steadily. Preparations are now made for the construction of the *gates* or passages for the iron from the external surface into the mould. In the moulding of a register-grate front there are usually four gates constructed, into which the iron is poured simultaneously. The necessity for having so many openings for the iron must be obvious, on considering that iron rapidly solidifies as it cools from a melting temperature, and of course *sets* in the form of the place it occupies.

To provide for the gates to the moulding, four taper pins of wood are stuck in the sand of the lower box at a short distance from the pattern, projecting upward between the ribs of the upper box. Sand is, as before, thrown into this box, covering the flat side of the pattern, and is rammed between the ribs until the box is filled flush with itself. The pins are now withdrawn, and the holes formed by them are widened at the top into bell-mouths to receive the iron the more readily, and are well smoothed there to prevent the metal from carrying in with it any loose sand. The upper box is now taken off with care, to preserve the impression of the upper side of the pattern; and the edges of the moulding in the box B, in contact with the pattern, are wetted with a swab to make the sand, at these corners, the firmer, and to prevent crumbling on withdrawing the pattern. Still farther to facilitate this, as the pattern fits closely in its bed, it must be loosened before being drawn, which is simply effected by taking hold of the pattern by a sharp point, if of wood, or by studs, which are rivetted into it when of iron, and gently tapping them laterally and downwards. The pattern is next drawn slowly out of the sand, and it often occurs that the moulding is broken at one or two places, in spite of these precautions, and especially if there be much carved or ornamental work on the pattern. The moulder has, therefore, in the first place, to repair the damages by adjusting disjointed parts, and making up fractures by the addition of sand. All the more prominent and most exposed parts of the moulding, as the extremities of the ornaments, are treated with a touch of the swab, which must be lightly applied so as not to spoil their sharpness. This process, indeed, with that of applying the blackening, now to be described, are the most difficult parts of the art of the flat-moulder. The blackening has now to be applied, and it must, by some means, be pressed down upon the mould at every part, and made to adhere to its surface. To effect this, pease-meal is used—it is first dusted thinly over the surface of the mould. It rapidly absorbs the damp of the surface sand, and is converted into a pasty matter. The blackening is next dusted over the newly formed paste, and over all, the pattern is placed in its position and pressed down. Thus the blackening is made as smooth as the pattern, and is at the same time well held down to the sand. Channels are now scooped out of the surface of the sand, joining the gate-holes to the moulding; and if the pattern be thin, each channel is widened as it joins the mould to afford a sufficient inlet for the iron. They are slightly swabbed round the mouth to confirm the edges against the abrasive action of the iron.

Having finished the moulding, and got it in order for the reception of the iron, the upper box is finally put on the under one in its place, and fastened down upon it. All is now ready for the pouring of the iron. In the adjoining figure of the boxes in this condition, the moulding is represented within, and the gates leading to it from the surface.



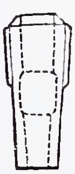
There are several points in the practice of green-sand moulding generally, to which great attention must be paid. In the preceding account, we alluded to the necessity of the sand being rammed as uniformly as possible. Now it may be too closely rammed altogether so as to impair its capability of conducting away the confined air and the gases generated by the heat. There must be a degree of ramming applied proportioned to the heaviness of the casting. If the sand be too closely rammed, the current of iron flowing over the moulding is agitated by the air not being allowed to pass freely off. In consequence, it breaks up the sand and heaves it to the surface, and it is easy to see that this produces excrescences on one side of the casting, while corresponding deficiencies exist, from the same cause, on the other side. If, again, the sand be too loosely rammed, the iron by its weight presses it outward off the moulding, which renders the surface uneven, and swells the casting. Moreover, a certain degree of humidity in the sand is necessary for the goodness of the casting. When the sand is deficient in moisture the iron is apt to penetrate its pores on the under surface, and so detach the particles of sand there, producing an effect similar to that occasioned by over-ramming. On the contrary, if there be an excess of dampness in the sand, the iron, by the sudden formation of aqueous vapour, is frequently repelled altogether, and ejected at the gate like shot. Should this not take place, though the iron may make its way through the mould, the bubbles of vapour form cavities in the casting towards the under side principally, as this side bears all the *run* of the iron passing over it, and is thus more severely tried than the upper side, the iron

simply rising to that side, and is there at rest. Excess of dampness, and of over-ramming, are thus nearly alike in their effects, and are the more dangerous extremes. In cases of very large castings, if the air expanded by the heat, and the other gases generated, do not find a ready vent, they burst through every resistance with explosive energy.

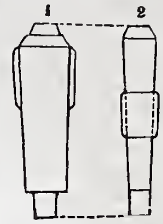
The quantity of blackening to be applied must also be a particular quantity. In noticing, in a former part of this paper, the nature of blackening, and the manner in which it is operated upon by the iron, reference was made to the continued evolution of gas by combustion. If then, by the action of the iron upon the blackening in the mould, too much gas be formed, it collects in globules, and forms corresponding indents in the casting. The skill of the green-sand moulder consists in so laying on the blackening as to produce equilibrium between the antagonistic forces of the iron advancing, and the resistance of the gas produced. After having been pressed down by the pattern, the loose blackening left is rubbed off and blown away. When this is not attended to, the blackening is raised in layers from the surface by the iron, and deposited in other positions, giving the casting, when cool, a rough, clouded appearance. In forming the surface of the blackening upon ornamental moulding, by pressing down the pattern upon it, care must be taken that the pattern be perfectly dried before being laid over the blackening; for if at all damp, this will adhere to it and take the pease-meal with it, and so destroy the moulding. And even though it be quite dry at first, yet it may, by lying too long in the sand, contract damp, and so spoil the mould. Swabbing is avoided when not essentially necessary, as the formation of vapour, by the contact of the iron with the water, is, as before noticed, apt to agitate the current and make the flow irregular. The object of forming the gate to one side of the moulding is to check the violence of the iron in motion, and to introduce it with regularity. Were the gate formed directly over the moulding, any delicate ornamental work below would be worn off by the continued action of the iron, though certainly it may be so placed, if the moulding at that part be plain. We noticed the necessity of a number of gates to the moulding. The number of these varies with the extent of the surface of mouldings in general, and also according to their thickness. A comparatively deep moulding might be well filled by only one gate, while another of just the same horizontal surface, but shallower, would require two or more gates. In short, there must be as many gates as are requisite to ensure the metal's having thoroughly filled the mould while it is yet liquid. The iron should, therefore, be run in as quickly as possible to fill the mould completely, and this is especially to be attended to in cases of light-flat and hollow moulding, as in these the extent of cooling surface is great, compared with the depth or thickness of the iron.*

Before dismissing the subject of light-flat moulding, one other elegant example may be described, introducing the use of three boxes for a moulding. The instance referred to is the moulding of the cast-iron bushes, which are fixed into the naves of the wheels of waggons and other vehicles, to sustain the wear of the axle.

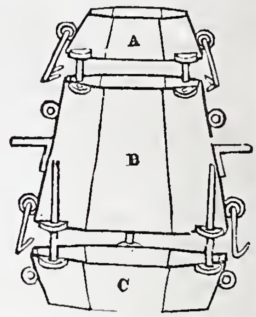
The annexed figure is a sketch of an ordinary bush for cart wheels. The dotted lines show the form of the interior, which is a tapered hole. At the middle of the length, as shown, a chamber is formed in the bush, so as to surround the axle—its object is to contain the grease for lubrication. These bushes are always cast in pairs, and the cores for them are cast-iron pins, having the form of the axles for which they are intended. These pins, which serve for many successive castings, are turned and polished in the lathe, for the purpose of communicating a smooth surface to the interior of the bushes, by which the expense is avoided of boring them out which would be necessary were sand cores employed.



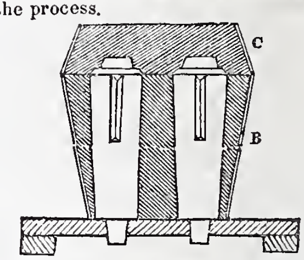
The pattern of the bush is solid, and has, in addition, a core print on each end to steady the core. This is shown by fig. 1, annexed. Fig. 2, shows the core extended at the ends in correspondence with the prints. Round the middle of its length a thickness of sand is rapped to form the grease-chamber in the bush. This part is made of sand, so as to be separable, and thus allow the core-pin to be driven out of the bush when cast.




The box in which the bushes are cast consists, as already mentioned, of three parts. The length of the middle part is made the same as that of the bushes between the small end and the tops of the feathers. The parts are octagonal in plan, as represented in the annexed figure. A the top, B the middle, C the bottom.

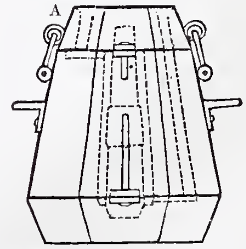



In proceeding to mould the pattern, a flat board is laid down level, with two holes in it at a suitable distance from each other. Upon this board a pair of bush-patterns are set down on their small ends, the points passing through the holes in the board to keep the pattern steady. The box B, is inverted and laid down over them, and filled with sand, which is rammed about the patterns level with the tops of the feathers on them. The box C, is now fixed on and rammed with sand. The figure annexed is a sectional view of the boxes and their contents at this stage of the process.

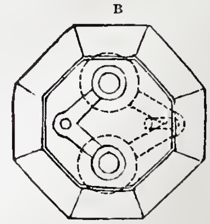



The two boxes together are inverted and set down—the box A is fixed on the uncovered end of B, and it likewise is rammed flush with sand. Two holes are next pierced downwards in the sand with the handle of the rammer, one to each side of the patterns. One of them extends just through the box A, the other reaches down to the box C. A and B, together, are lifted off C and turned over, the patterns, loosened by tapping, are next drawn out. A and B are then separated. Two prepared core-pins are next set, as vertically as possible, into the recesses left by the prints in the sand of the lowest box; on the surface of the sand, at each end of the box B, channels are cut joining the gate-holes, made by the rammer, to the two mouldings, in such a manner as that the short gate will be connected with the upper end, and the long gate with the under end of the mouldings. B is lowered over the cores, and fixed to C, being directed by the long guide pins at the side. A is next replaced, guided also by pins, and fixed to B. It must be placed with care, as the upper ends of the cores are at the same time entering the recesses made by the prints. And thus the cores are secured between the boxes A and C.

A



B

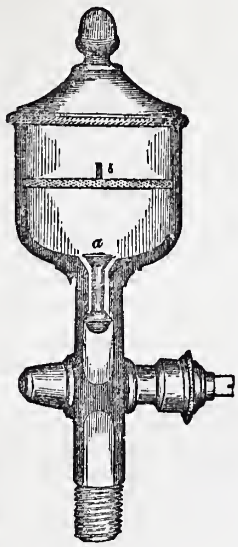


The moulding, as thus finished, is shown in figure A, which is an external view of the whole, with the interior arrangement in dotted lines. Fig. B is a view of the upper and under ends of the middle box, showing the gate channels. The iron is poured into the long gate, falling against the bottom of it, the force of the iron is broken, and it runs gently into the mouldings, rising within them till they are filled, when it passes into the short-flow gate, as it is termed, from which it issues, carrying off the refuse it may have gathered in its passage. Blackening is not applied to these moulds, as their roughness is of no consequence.

* Mr Neill's patent tiles for roofs afford a remarkable example of the extreme thinness of casting practicable. These tiles are each 18 inches by 6 inches, and weigh 28 lbs. per square yard, which gives one twenty-fourth of an inch for their thickness. Small as they are they require two gates on account of their extreme thinness.

## HORWOOD & MONKMAN'S AUTOMATIC LUBRICATOR.

The very ingenious apparatus here figured, is employed as a lubricator for steam engine cylinders, and is found to answer its purpose effectually, as the lubricating substance is supplied with the greatest regularity, and the waste consequent upon the old mode of oiling by hand is avoided.




The double valve *a* works loose in the tube at the foot of the cup, sufficient room being left between the spindle and the interior of the tube to allow of the passage of the oil. In the position of the valve, as here shown, the steam is supposed to be acting against the upper side of the piston of the engine to which this lubricator is attached, so that it also acts against the lower side of the double valve *a*, keeping it pressed against its seat, at the same time the upper valve is raised and allows the oil to pass into that portion of the tube which is between the two.

Immediately upon the ascent of the piston, the pressure of the atmosphere, caused by the condensation of the steam in the upper portion of the cylinder, acting upon the upper side of the valve, causes it to descend, thus closing the upper passage and opening the lower one, allowing the oil contained between the two to pass into the cylinder. A strainer of fine wire gauze, *b*, is placed in the cup for the purposes of cleansing the oil from impurities. The quantity of oil injected at each stroke may be regulated by means of the cock beneath.

# NATURAL PHILOSOPHY AND CHEMISTRY.

## CHAPTER III.

### HEAT.

It is highly doubtful whether the subject of heat belongs most properly to mechanical or to chemical philosophy, and the inquiry does not seem to be important. Its influence in producing chemical changes is unquestionable, and its mechanical effects are no less remarkable and decided. But the phenomena which it brings about are so blended together in their chemical and mechanical characters, and so connected as the effects of a common cause, that all attempts at a classification, founded on mechanical and chemical distinctions, could only lead to confusion and repetition; and as the subject cannot with propriety be omitted either in a course of natural philosophy or chemistry, we have preferred to consider it here in a general way, without attempting to discriminate between the relations which it bears to the one department and the other.

Heat, indeed, on account of its universal agency, and the importance of a knowledge of its nature and laws, ought perhaps to be reckoned a distinct branch of scientific inquiry. All the objects of the material world are under its influence, and are modified by it either in their mechanical or chemical properties, and often in both. The operations of nature in which it is concerned, are perhaps among the most interesting and the most intricate which any department of physical science undertakes to investigate. There is no physical agent whose intimate nature is more hidden, and whose laws are of more delicate and difficult examination, and yet whose influence is more manifest and more subservient to our physical well-being. To the present constitution of material nature it is indispensable. The modifications of matter which we recognise under the names of solids, liquids, and gases, are referrable to it; and, in consequence, all that we admire in the verdure of the earth, the fluidity of its waters, and the freshness and elasticity of the air we breathe. Its influence is necessary to make plants grow, put forth their flowers and perfect their seeds; and it is intimately connected with the power of life itself, since animation ceases when heat is withdrawn. In the operations of nature it seems indeed to be the prime mover—the life in short of the universe. Our winters are cheerless and dreary because it is deficient,—a numbness seems to steal over nature's vital functions,—a greater deficiency produces the permanent torpor of the polar regions. And could we imagine the genial influence totally withdrawn, what would follow? The limited experience we derive from our seasons and climates, independent of all scientific deductions, clearly points to the doom which would settle upon our world and the life and volition with which it teems. Our experience is enough to tell us, that the whole globe we inhabit, would be an impenetrable rock, indissolubly bound up in chains of cohesion. The waters having ceased to flow, and the air having settled down to a still and useless mass, there would exist no order of living creatures with which we are at present acquainted to break the pervading solitude; there would exist only inert matter, silence, desolation and death. The laws which regulate the motions of our planet among the other worlds of the planetary system might remain unaltered; our globe might continue to perform its annual circuit among the stars of the firmament, and it might turn on its axis with the same accuracy as now, but to what purpose? It had no useful function to perform among the works of creation, —it was a body without a soul, a death-ship in the eternal ocean of space.

In the provinces of art, the effects and phenomena of heat are continually before our eyes as matters of the most common occurrence. By its aid, "matter is modified in ten thousand ways, and rendered subservient to the uses of man, furnishing him with useful and appropriate instruments, warm and ornamental clothing, wholesome food, needful and effectual shelter." Man indeed surrounds himself with fire,—he employs it to rend for him the solid rocks, and bring forth the hidden treasures which the earth contains. It is with fire that he melts metals, vitrifies sand, hardens clay, softens iron, and gives to all the productions of the earth the forms and combinations which his necessities require, or which his ingenuity may suggest. But not only is heat subservient to all the departments of metallurgy, of glass, porcelain, and soap-making, and sugar-refining; not only is it useful in the domestic arts—to the baker, the brewer, the distiller, and a thousand others, it is the actuating principle of the mighty steam-engine itself, which the ingenuity and perseverance of man has trained to perform half the labour of society.

Among the first questions which occur to us in regard to this important agent is,—what is it?—is it material or immaterial, a matter of a peculiar nature or a condition of material things? As yet these questions have only been answered hypothetically, and the discussion can only be entered upon with an extended knowledge of the properties of heat as a power, and the phenomena which it brings about; and fortunately all these can be examined, and the existence of the power itself clearly recognised in the effects which it produces, without inquiry into the intimate nature of the power itself. The effects also, their relations to each other, and the general laws according to which they are produced, can all be investigated with sufficient precision, independently of any knowledge as to the material or immaterial nature of the primary agency. In order therefore to avoid all unnecessary difficulties, we shall defer for the present the consideration of all hypotheses as to the nature of heat, and turn our attention to the phenomena which present themselves naturally for our examination.

Whether heat be a substance or a quality, we find that it is readily transferrable from one body to another. A piece of iron placed in a bright fire, speedily becomes like the burning coals, red hot. It is upon this property that we depend for the maintenance of our fires, and all our methods of artificial illumination. Our commonest experience further informs us, that the transfer of heat from one body to another is not limited to cases of actual contact: we approach a fire to warm ourselves, and while we are conscious that the fire has the power of exciting in us the sensation of warmth, we do not for a moment suppose that it is the material particles of the coals composing the fire which reach and warm us. When we feel the same sensation from the sun's rays, we readily admit that it is not the constituent matter of that body which reaches us. And taking these facts into con-

sideration, we are led to the inference, that there is an agent distinct from the peculiar substance of the body residing in its mass, transmitting itself to great distances, and establishing betwixt us and it a continual communication: this agent is the *cause* of the sensations of heat and cold which we experience. It is to this cause that we give the name *heat;* but as this seems to confound the cause and effect, the term *caloric* has been proposed as a specific name for the agent producing in us the sensation to which we give the name heat. It is in this sense that the word caloric is used in modern books of science; but its introduction does not appear to be very necessary when the meaning which we are to attach to the word *heat* is explained. We form, for instance, just as clear a conception of the "*heat* of the sun's rays," as we do of the "*caloric* of the sun's rays," and the first expression has the advantage of being more conformable to our common modes of speech. And again, when we speak of feeling *heat*, our meaning is understood without difficulty as applying to the sensation produced by heat as the cause. In conformity, therefore, with the more general usage, we shall continue to employ the word heat both with reference to the cause and the effect. This, we believe, can lead to no confusion.

The correspondence which we readily recognise between the influence of heat on our organs of sensation, and its effects on inorganic substances, lead us at once to assign the modifications which we witness and feel to a common cause. The heat that warms us would melt ice; and water can be made to boil under ordinary circumstances only by a heat that would burn us. It is from considerations of this nature that we derive our first systematic knowledge of heat. They are the foundation of our classification of its effects and the laws by which these effects are brought about; and taking advantage of the order in which the phenomena most naturally present themselves to our notice, we shall consider the effects of heat as shown in the expansion and change of the state of bodies, its communication, the quantity of heat which substances contain, and the production of heat and cold; reserving all speculative considerations regarding the nature of heat, till we have taken a survey of its physical effects.

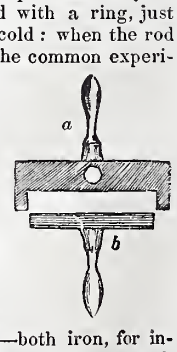
We have already remarked that heat is readily communicated from one body to another. If a hot plate of metal be laid on another that is cold, the former loses heat, and the other acquires it: the heat after some time is nearly equally divided between them. Similarly when the red-hot heater of a tea-urn is placed amidst the water, it yields heat to it till both become equally warm; and in general when hot and cold bodies are placed in the vicinity of one another, there is a loss of heat by those which are hot, and an acquisition of heat by the cold bodies. These are cases illustrative of the diffusion of heat and the establishment of what is technically called an *equilibrium of temperature.* But a question occurs,—what is *temperature*? The term, like many of our everyday words, is perhaps not resolvable into any terms more simple. We use it very commonly as synonymous with heat itself; but in a strict sense it denotes the state of a body with regard to its disposition to give or receive heat as referred to a standard. The temperature of a substance is raised by receiving heat, and lowered by giving it out; temperature therefore depends on the quantity of heat present. The varying sensations of heat and cold which we experience give us some information, which are worthy of notice. On touching a substance the temperature of which is higher than that of the body, heat passes from it to the hand, and excites the feeling of *warmth* or *burning* according to the intensity of the heat, that is, the highness of the temperature; on the contrary, when we touch a substance, the temperature of which is low compared with that of the body, heat is communicated to it from the hand, and this giving away of our natural heat is what excites in us the sensation which we call *cold.* Heat and cold, then, considered as existing in the bodies themselves, although thus appearing opposites, are really degrees of what we call *temperature*, contrasted for convenience' sake in reference to the particular temperature of the person speaking of them, just as the milestones on a road, although merely marking degrees of the same object; *distance* from a place might receive from persons living between them, the opposite names of east and west, or south and north.

We shall now proceed to inquire into the effects which are produced upon bodies by a change of temperature, that is, by the accession and diminution of heat in their substance.*

### § 1. OF THE EXPANSION OF BODIES BY HEAT.

The most general and remarkable effect produced upon bodies by the absorption and the emission of heat, is alteration of volume: all bodies in nature, solids, liquids, and gases, are increased in dimension, when heat is diffused through their substance, and contract again to their former volume, when they regain their former temperature. It may be asked, how it is that heat effects these alterations of volume? The question is answered by reference to the meaning we here attach to expansion; and to see in what this ultimately consists, we must bear in mind, that all material things are made up of integrant particles—that these particles are held together by cohesion, acting strongly in solids, and slightly in liquids, and that the body exists in a gaseous state when the cohesive force is removed. These gradations, then, of the force of cohesion is that which regulates the state of a body, and any force which is capable of counteracting it, must, at the same time be capable of altering the molecular distances—that is, the relative distances of the constituent particles from one another. This is exactly what heat effects—it is the repulsive principle which nature has set up to operate as the antagonist of cohesion—it removes the molecules of matter farther asunder, making them occupy more space, and the consequence is, an increase of the general volume; and this increase of the general volume is what we understand by *expansion.* From this explanation, it may be anticipated, that a small addition of heat will occasion a small expansion, and a greater addition of heat a greater expansion; and further, that whenever heat passes out of a body, the cohesion being left to act more freely, contraction of volume will ensue. It follows, moreover, from this view, that the less the cohesive force, the greater will be the expansive effect of heat—an inference which we shall see is fully justified by reference to the three states in which matter exists. Thus, in solids, the force of cohesion being great, the expansion is trifling in amount; in liquids, where it is less, the expansion is much more considerable, and in aëriform substances, where the cohesive force is least, the expansion is by far the greatest. We shall consider these circumstances in their order.

*Expansion of solids.* In proof of the expansion of solids, we need only take the exact dimensions of length, breadth, and thickness, of any substance when cold, and measure it again while strongly heated: it will then be found to have increased in every direction. A familiar demonstration of the fact is afforded by the circumstance, that a lead bullet, which at the ordinary temperature of the atmosphere, just passes freely into the barrel of a gun, cannot be forced in without great exertion, while at a temperature of boiling water. The same experiment may be conveniently made, by fitting a metallic rod with a ring, just large enough to move freely when the rod is cold: when the rod is hot it will not pass through the ring. The common experiment shown by lecturers is made with an apparatus, like that figured in the margin. This consists of a brass rod $b$, of such length, that when cold it just enters lengthwise between the projections, at the ends of a flat iron piece $a$, and by its ends passes into the round hole. When the piece $b$ is heated in the fire, it is found to be too long to pass between the projections, and too thick to enter the hole; as it cools it will be found to resume gradually its original dimensions, and will ultimately fit as before.




Were the bar and the gauge both of the same metal—both iron, for instance—it is easy to see that if they were made to fit when cold, they would fit at all equal temperatures; for the one would expand as much as the other; but we have here supposed the bar to be brass, and the gauge iron; and it is found that when both are made red-hot, that the parts of the apparatus do not fit. This then suggests another fact, that although both metals expand, they expand differently, and the brass more than the iron. The expansion of solids being small, it requires nice admeasurement to ascertain its amount; yet sufficiently accurate means have been found to establish the fact, that the amount of dilatation is different in different bodies—that, indeed, there are hardly any two solids which expand exactly alike. For instance, on raising

* If the reader is not at all acquainted with the thermometer and its uses, it may perhaps be advisable that he consult the description of that instrument given in the last section of this chapter, before proceeding further.

the temperature of the following substances, from the freezing to the boiling point of water—

| | | | |
|---|---|---|---|
| Zinc elongates | 1 on 333 | Soft iron forged, | 1 on 818 |
| Lead, | 1 — 350 | Cast-iron, | 1 — 900 |
| Tin, | 1 — 488 | Steel, untempered, | 1 — 926 |
| Silver, | 1 — 523 | Steel, tempered, | 1 — 806 |
| Brass, | 1 — 532 | Glass without lead, | 1 — 1114 |
| Copper, | 1 — 580 | Platinum, | 1 — 1166 |
| Gold, | 1 — 681 | Flint glass, | 1 — 1248 |

This, as stated, is the increase which these bodies sustain in length, but as they dilate in all their dimensions, their increase in general bulk will be about three times greater: it may therefore be readily found by dividing the given numbers by 3. Thus, if zinc elongates 1 inch in 333, it will dilate in cubic capacity 3 inches in 333, or 1 in 111.

The expansion of solids has engaged the attention of several experimenters, and besides the general fact of dilatation by heat, and contraction by cold, and that different solids expand differently, their experiments have further proved, that the dilatation of the same body is not equal for equal additions of heat, but goes on increasing with the temperature. For instance, MM. Dulong, and Petit, found that

| | | | | | |
|---|---|---|---|---|---|
| glass from 32° to 212° | that is, | for 180° | elongates | 1 on | 1160 |
| " from 212 to 392 | " | for 180 | " | 1 " | 1088 |
| " from 392 to 572 | " | for 180 | " | 1 " | 886 |

This, indeed, is nothing more than might be inferred, by reflecting on the nature of expansion; for heat being the power opposed to attraction, it tends to separate the particles of the substance which it enters, and every accession weakens cohesion, and renders the next portion which is introduced more efficacious.

Some idea of the prodigious force with which the expansion and contraction take place, may be had from the reflection, that it is equal in amount to the mechanical force which would be necessary to produce similar effects in stretching or compressing the bodies in which they take place: thus, a bar of iron heated so as to increase its length a quarter of an inch, by this slow and quiet process, exerts a power against any obstacle by which it may be attempted to confine it, equal to that which would be required to reduce its length by compression to an equal amount: on withdrawing the heat, it will exert an equal power in returning to its former dimensions. Such force is often made available in the arts. The iron hoops of casks, for instance, are driven on in a hot state, and are then suddenly cooled, by throwing water upon them; the contraction of the iron which ensues brings the parts of the vessels into closer contact, than they could easily be brought by other means, and fixes the hoops firmly round them. The parts of carriage wheels are bound together in a similar way; the iron band, or *tire* as it is called, is made a little smaller than the circumference of the wooden part of the wheel: being put on while in a state of expansion by heat, it is suddenly cooled, and by its contraction, binds the wood-work of the wheel—the *felloes*—together with enormous force. The plates of boilers for generating steam are rivetted together with hot rivets, which in cooling draw them together more effectually, and render their junctions perfectly compact. Experience has taught engineers, that it is dangerous to attempt to confine such a force as this, and accordingly we find provision made for expansion and contraction in all structures where metallic elements are combined with less expansive materials. In iron pipes for the conveyance of hot air, or steam, through a factory, when of considerable lengths, some of the junctions are rendered moveable, so that by the end of one pipe sliding into that of another, the accidental changes due to the temperature are provided for. They are, moreover, never allowed to abut against a wall, or obstacle, which they might in expanding overturn. Dr Arnott relates, that an incompetent person undertook to warm a large manufactory by steam: he laid a rigid main pipe along a passage, with lateral branches, passing through holes into the several apartments: on his first admitting the steam, the expansion of the main pipe tore it away from all its branches. This is exactly what a competent person would have foreseen. Even contemplating only the common atmospheric changes of temperature, the expansion of metals is an element not to be neglected. The centre of an arch of an iron bridge, is higher in warm, than in cold weather, and on the contrary, in a suspension or chain bridge, the centre is lower. Both of these cases, therefore, require provision to be made for them, otherwise destruction would ensue. The same principle points out the necessity there is of attending to the nature of the materials united together for particular purposes. Glass and platinum expand very nearly alike, and hence the possibility of cementing them together, as is done in many chemical instruments; but were we to attempt to do the same with any other metal, the first change of temperature would destroy the junction. The cope-stones of walls are sometimes held together with clasps of iron: if these are of cast iron, which is brittle, many of them usually give way on the first frost from a tendency to contract more than the stone will permit; if they are of malleable iron, they generally crush the stones, and loosen themselves in their sockets. "The steeple of Bow church (London) has within these few years been nearly thrown down by the alternate expansion and contraction of some rods of iron, which were built into it, to give it stability. The rods in hot weather lengthened, and lifted the incumbent mass of masonry; they returned in cold weather to their former dimensions, leaving the stones upraised, and resting on dust, and sandy particles of matter, which made their way into the cracks thus produced; the rods again lengthened, and lifted the mass a little higher; till by numberless repetitions of this slow but irresistible operation, the fabric was shaken to its foundations."—*Daniel's Chemical Philosophy.*

There are some mechanical operations in which it is necessary to determine the amount of expansion and contraction of the metals employed with the utmost degree of accuracy. This is particularly the case with astronomical instruments and instruments employed in laying down the base line of a trigonometrical survey, where the error of an inch in a mile would be fatal. The same accuracy must be attended to in regulating the rate of going of a clock. When the length of the seconds pendulum is increased only the hundredth part of an inch, the clock loses ten seconds in twenty-four hours; and a change of temperature of only thirty degrees, if the pendulum be of the common sort with an iron stem, will occasion an error in the rate of going of eight seconds a-day. Variations of temperature also occasion variations in the oscillations of the balance-wheels of watches. These effects are obviated by various compensating apparatus, depending upon an accurate comparison of the different expansibilities of the metals employed.

A compound bar, made by soldering or rivetting together two thin rules of steel and brass, (or better, copper and platinum,) affords a good illustration of unequal expansion by heat. At the temperature of the bars, when they were put together, the compound bar will be straight, as in *Fig.* 1.; but the brass being more *expansive* than steel, it will assume the form shown in *Fig.* 2. when exposed to a higher temperature, and the brass being likewise more *contracted* than the steel, it will take the form shown in *Fig.* 3. at all inferior temperatures.

*Fig.* 1.

*Fig.* 2.

*Fig.* 3.

It is not difficult to conceive, that by a "proper attention to the expansions of the metals of which it is composed, a bar of this kind might be constructed, that although it was heated and expanded, its extreme points should always remain at the same distance from each other, the length being compensated for by the bending. The balance-wheels of chronometers are preserved invariable in their diameters during all temperatures by a contrivance of this sort." The solid thermometers of the Messrs Breguet of Paris, and of Mr James Crichton of Glasgow, are made upon the same principle, the degree of curvature being the measure of the increase or decrease of temperature.

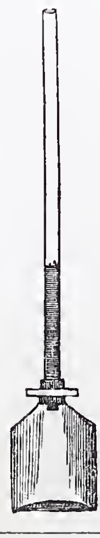
Were such a bar as that instanced above formed of two differently expansible but inflexible substances, it is obvious that it would be destroyed on the first considerable change of temperature to which it was submitted; and exactly the same result would follow, although both the parts were equally expansive, if the temperature of the one was raised higher than that of the other. This explains why glass is so apt to break when heat is applied to it. When hot water for instance is poured suddenly on a thick plate of that material, the upper surface is heated and expanded before the heat penetrates to the lower surface: the glass tends to bend like the compound bar, but is fractured in consequence from its want of flexibility. Every one knows how apt a tumbler is to break when hot water is poured into it suddenly

while in a cold state, and that the best mode of avoiding such a catastrophe is to heat it very gradually, allowing time for the heat to permeate thoroughly, but gradually, the whole substance of the glass, and the whole to expand alike; it is not expansion but *inequality of expansion* which is to be guarded against. From what has been said, it will also be observed, that the danger increases from the thickness of the glass: boiling water may be poured into very thin glass vessels without danger, because the heat penetrates the whole substance very rapidly, and they have moreover a slight degree of flexibility which adds to their safety. Cut glass is still more readily fractured than plain, from the inequalities in its thickness: tumblers of this description ought to be eschewed by all toddy drinkers. Other brittle substances are liable to the same accidents as glass: heated plates of cast iron are broken by pouring water upon them; a common pot, if placed on the fire empty and allowed to get hot, will be apt to break if water be then poured into it.

Both cast iron and glass are peculiarly liable to accidents when in the state of flat plates. Plate glass, indeed, can never be heated without risk of its breaking: thus electrical-machine plates are often broken by setting them before a fire even when every attention is given to heat them uniformly. The flat iron plates, placed across chimneys as dampers, are very apt to split when they become hot; and much inconvenience has often been experienced in manufactories from this cause. A slight curvature in their form has been found to protect them most effectually.*

The unequal expansion and contraction of glass, on the sudden application of heat or cold, are often turned to advantage by glass-blowers. Watchglasses are also by this property readily cut out of a globe of glass by conducting a crack in a proper direction by means of an iron rod or piece of tobacco pipe heated to redness. The chemist likewise avails himself of the same means to divide damaged globes into capsules, and indeed to convert many sorts of broken vessels into articles of use.

One of the latest discoveries of importance, on the dilatation of solids by heat—and one which is likely in future to be of use in leading to a knowledge of the intimate structure of crystallized bodies—is the observation of Professor Mitscherlich, that the angles of some crystals are affected by changes of temperature. This shows that the bodies of crystals do not expand or contract uniformly, but more in one direction than another; and indeed Mitscherlich has very satisfactorily shown, that while a crystal is expanding in length by heat, it may be contracting in another dimension. Thus the angles of a crystal of calcareous spar vary eight and a half minutes of a degree between the freezing and boiling points of water; the obtuse angles diminishing, and the form approaching more nearly to that of the cube. This unequal expansion is not however observable in crystals of which all the sides and angles are equal, as the cube, the regular octohedron, and the rhombic-dodecahedron. The detection of the irregularity, in all cases where reference must be made to absolute measurement, is one of great delicacy; but common observation is familiar enough with the same fact under a different form. Melted litharge, for instance, allowed to cool and solidify, flies into fragments when it reaches a certain point, in consequence of its irregular contraction. The double sulphate of potash and copper exhibits the same phenomenon in a still more remarkable manner. When a little of this salt is melted, and the heat withdrawn, it becomes a beautiful green solid, and remains in this state till the temperature sinks to about the heat of boiling water, when all at once its cohesion is destroyed, and the whole becomes a heap of incoherent powder.



*Expansion of Liquids.*—In liquids, as already remarked, the expansive force of heat is little resisted by cohesive attraction; and dilatation is in consequence much more considerable in them than in solids. This is strikingly exhibited by filling a three or four ounce phial with water, and inserting into it a perforated cork having a small glass tube passing through it perfectly tight, and immersing the phial in hot water, or what is better, hot oil.† The expansion of the water in the phial will cause it to mount rapidly in the tube. This simple experiment is indeed illustrative of two facts: it proves first that the dilatation increases with the temperature; for the longer heat is applied (within the boiling point of the liquid), the higher it rises; and, secondly, that liquids expand more than solids; for the glass phial is itself expanded by the application of heat, and its capacity is consequently enlarged; but it is clear that if the enlargement of the glass were equal to the expansion of the liquid, no ascent in the stem would be perceived. The ascent then of the liquid in the tube marks the difference between its own dilatation and that of the glass, and the height is its apparent not its real expansion.

Liquids, like solids, differ in their relative expansibilities; ether is more expansible than alcohol, and alcohol more than water, and water more than mercury; and it may be stated generally, that those liquids are most expansible which boil at the lowest temperature.

Thus by the same change of temperature—

| | | | | |
|---|---|---|---|---|
| 1000 | parts of water | become | 1046 | parts. |
| 1000 | — of fixed oil | — | 1080 | — |
| 1000 | — of spirits of wine | — | 1110 | — |
| 1000 | — of mercury | — | 1018 | — |

From this it appears that spirits of wine is two and a half times more expansible than water, and six times more expansible than mercury. "The difference in the heat of the seasons affects sensibly the bulk of spirits. In the height of summer spirits will measure 5 per cent more than in the depth of winter." And hence a cunning dealer will contrive to make his chief purchases in winter, and his chief sales in summer.

Equal additions of heat do not occasion in liquids, any more than solids, equal degrees of expansion at all temperatures: all are progressively more expansible as the temperature augments. This may be observed by applying the heat of a spirit lamp to a liquid contained in a bulb with a tube to it, differing only from that above described, by having the tube marked off in its length into a number of equal parts. The number of divisions past which the liquid rises during the first minute being observed, the same heat continued the next minute will occasion a greater expansion than before; the ascent in the tube will be still greater during the third minute, and so on; every successive addition of heat applied producing an increased effect, until the water, or other liquid employed, arrives at the boiling point. This, as before noticed in the case of solids, is readily explained by reference to the ultimate nature of expansion, and the continually decreasing force of the cohesive attraction. It may be likewise anticipated, that those liquids are the most equably expansible which boil at the highest temperature. Thus the boiling point of mercury is high, and its expansions are so uniform as to render it, as will afterwards appear, extremely proper for the construction of thermometers. From the use of this liquid for several philosophical purposes, its rate of expansion has been determined with extraordinary care, especially by Dulong and Petit, who have found that it expanded when not enclosed in tubes—

| | | | | | | |
|---|---|---|---|---|---|---|
| From | 32° to 212° | that is, 180°,— | $\frac{1}{55.5}$, | or 1 | measure on | $55\frac{1}{2}$ |
| — | 212 to 392 | — 180 — | $\frac{1}{54.25}$, | or 1 | — | $54\frac{1}{4}$ |
| — | 392 to 572 | — 180 — | $\frac{1}{53}$, | or 1 | — | 53 |

When mercury is confined in glass tubes it expands—

| | | | | | | |
|---|---|---|---|---|---|---|
| From | 32° to 212° | that is, 180°, | $\frac{1}{64.8}$, | or 1 | meas. on | $64\frac{4}{5}$ |
| — | 212 to 392 | — 180, | $\frac{1}{63.78}$, | or 1 | — | $63\frac{3}{4}$ } nearly. |
| — | 392 to 572 | — 180, | $\frac{1}{63.18}$, | or 1 | — | $63\frac{1}{5}$ } nearly. |

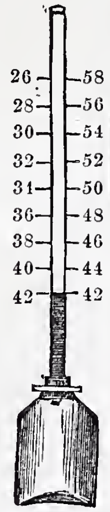
This progressive expansibility is very remarkable in water. This fluid, while receiving the increase of the $22\frac{1}{2}$ degrees of temperature nearest the boiling point, expands very nearly five times as much as it does by heating it $22\frac{1}{2}$ degrees above the ordinary natural temperature, ($54\frac{1}{2}$°.)

We have intimated that the law of expansion by heat is universal; but within certain limits of temperature, water presents a most remarkable exception to this law. Ice, as every one knows, swims on the surface of water, and, therefore, must be lighter than it. This itself is a convincing proof that water expands at the moment of freezing. But were this all, the fact would not be singular; for many saline solutions, and even some metals, as antimony, bismuth, and zinc, suffer considerable expansion at the moment of passing from a fluid to a solid state. Facts of this kind are referrable to a new and peculiar arrange-

* Graham's Elements of Chemistry.

† A glass bulb with a long tube to it would of course be more convenient for this experiment; but the apparatus here described and figured is not only more easily procured, but, with a little modification, it serves for various other experiments which we will have occasion by and by to mention.

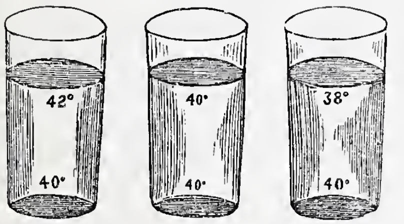
ment of the constituent particles—a new molecular structure of the bodies, brought about under the prevailing force of cohesion, giving rise to the phenomena of crystallization. But it is not merely during the act of congelation that water expands: the expansion begins nearly eight degrees above that point (at $39\frac{1}{2}°$). This is easily rendered obvious by the following experiment, which may readily be performed with the phial and tube already described. Fill this with pure water at the ordinary temperature (say 60°), to about the middle of the tube; then immerse the phial in a freezing mixture (pounded ice and salt), and the water will immediately begin to fall in the tube, marking contraction; but in a short time an opposite movement will be perceived, indicating that dilatation is taking place notwithstanding that the cooling process is still going on.




It has been objected to the inference deduced from this experiment, that the ascent of the water in the tube is referrable to the contraction of the phial whereby its capacity is reduced, and not to the expansion of the liquid itself; and, in fact, this is true to a certain extent, but it is by no means sufficient to account for the whole effect. It is nevertheless curious to remark in this experiment, that when accurate means are taken to estimate the temperatures of the liquid, both when heated and cooled, that it expands equally on both sides of 42°; that is, when cooled to 40°, it rises to the same point in the tube as when heated to 44°; at 32°, it stands at the same height as at 52°, and so on for different temperatures, as illustrated in the graduation of the figure.*

The admirable researches of Dr Hope afforded the first true demonstration of the expansion of water below 40°, and the vast importance of this exception to the law of expansion by heat.† He filled a deep glass jar with water at the temperature of 50°, and immersed in it two small thermometers, one near the surface, and the other at the bottom of the jar. Thus prepared, the jar was placed in a very cold room, and the indications of the thermometers were carefully watched. Now it must be borne in mind, that any body, by expanding, must become lighter, bulk for bulk. This is easily proved by pouring a pint of boiling water into one scale-pan of a weigh-beam, and a pint of water at the ordinary temperature into the other: the latter will preponderate. The cold water is therefore more dense; that is, contains more matter in a given bulk than the hot water. If water, which is warm and expanded, be therefore poured cautiously on the surface of cold water, it will continue to occupy the upper part of the vessel in the same manner, though not so distinctly as oil would do: this may be proved by colouring the warm water with a little litmus, or the like. And what is true of water expanded by heat, must be true of water expanded by cold, which is deficiency of heat to a certain extent, as already noticed. These facts, then, afford a key to the indications of the thermometer in the experiments; these were as follows: the upper thermometer indicated a temperature several degrees higher than the under one till the temperature fell to 40°; that is, "the chilled water fell as usual to the bottom of the jar, or became denser as it lost heat (as illustrated in figure 1.) At 40°, the two thermometers were for some time steady (as shown in figure 2); but as the cooling proceeded beyond that point, the instrument in the higher situation indicated the lower temperature (as shown in figure 3); that is, the water now as it became colder became lighter, and rose to the top."

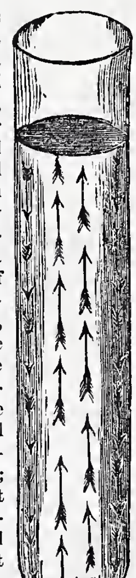
*Fig. 1.* Cooling above 40°. *Fig. 2.* *Fig. 3.* Cooling below 40°.




To remove all source of doubt, Dr Hope reversed his experiment: he filled the jar with water at 32°, and placed it in a warm room. The temperature of the water gradually rose, and the indications of the thermometers were exactly as before, except that fig. 3 must be reckoned fig. 1, and fig. 1 as fig. 3. Either of the methods of conducting the experiment is perfectly conclusive of the fact that water is expanded by being made colder than 40°.

This property of water is not only curious in itself as a marked exception to a law which is all but universal, but is of the utmost consequence in the economy of nature. Let us see how it operates: the cold season—our winter—sets in, and the surfaces of our rivers and lakes become cooled by contact of cold air and other causes. The superficial water so cooled, sinks, giving place to the warmer water below; this in its turn is chilled, and sinks in like manner. The progress of cooling in this way goes on with considerable rapidity, so long as the cold water descends, and exposes that not hitherto cooled. But this *circulation* ceases when the whole mass is cooled down to about 40°, which is still eight degrees above the freezing point; the upper surface no longer sinks as it loses its heat, but remains on the top from its lightness, and ultimately freezes. The ice may thicken, but it is a bad conductor of heat; and the consequence is, that at the depth of a few feet, the temperature of the water is maintained at 40°, which is high when compared with that frequently experienced, even in this climate during winter. Now, what would have been the consequence had water not presented this anomaly but continued to become heavier until it had arrived at the freezing temperature? The answer is obvious: the circulation we have spoken of would go on, not until the body of the water was cooled down to 40°, but until it had reached the point at which congelation takes place; and this point once attained, the evident consequence would be, that the whole body of water would rapidly be converted into ice, to the destruction of every living being that inhabits it. Our warmest summers would make but little impression on such masses of ice; and the cheerful summers which we at present enjoy would be less comfortable than the frozen regions of the poles. Upon such delicate and beautiful adjustments do the order and harmony of the universe depend.*

The diffusion of heat in liquids is similarly explained. Knowing that when a liquid is heated, it expands and becomes lighter, we can readily conceive that when a vessel containing water is placed on the fire, the layer of water on the bottom becomes heated, and, in consequence, ascends in the same manner as a cork, or any other light body, would rise, and diffuses a quantity of its heat through the mass of fluid. This portion of heated water having been thus removed by its lightness, the next layer now in contact with the bottom, or source of heat, becomes heated in its turn, and ascends; and so on, layer after layer is heated and ascends until the water boils. The rapidity with which heat is thus conveyed, is easily exhibited by means of a very simple apparatus, a glass tube containing some water. Applying the flame of a lamp at the bottom of the tube, the circulation of the fluid will at once be rendered obvious by diffusing a small quantity of any light insoluble powder, (bruised amber for instance,) in the water. The directions of the arrows in the figure point out the movement of the currents. It may further be observed, that any viscosity in the liquid will impede its motion. A little gum-arabic, for instance, will considerably retard its boiling. Farinaceous substances, for this reason, allow water to boil slowly; but when such a mixture has once acquired heat, it parts with it equally slow. Many a person, however, has burned his mouth with hot porridge, and wondered at the slowness of its cooling, without being able to assign the philosophical reason of his misfortune.



The circulation of heated water on this principle through an endless tube, is now commonly and advantageously

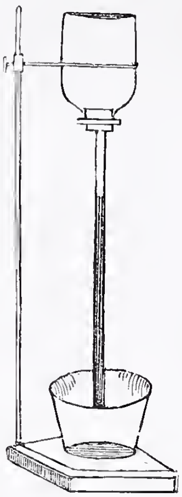
* Graham's Elements of Chemistry. If caution be used, the water may be cooled down to 25° below its freezing point to a fluid state, and will continue to expand.

† Philosophical Transactions of Edinburgh, v. 379. We have taken 40 degrees as the temperature of the greatest density of water; but Dr. Hope estimated it at $39\frac{1}{2}°$, and an elaborate experiment of Hällstrom, (Annales de Chimie et de Physique, t. 28, p. 90,) has since shown that the point of greatest density is 39° 38′. We use 40 to avoid fractional numbers.

* Graham's Chemistry, Arnott's Physics.

applied as a means of warming some hothouses, factories, and other large buildings.

*Expansion of Gases.* As the particles of air and aeriform bodies are not held together by cohesion, they are more expansible by heat than matter in the other two conditions of liquid and solid. This is well illustrated by the simple apparatus of the phial and tube already described. Let the phial be about one-third filled with coloured water, and let the tube be pushed through the cork till its lower extremity is some way into the water. Thus prepared, the heat of the hand grasping the phial will cause the water to ascend rapidly in the tube. This is caused by the expansive air pressing upon the surface of the water, with such force as to balance a considerable column of the liquid in the tube. This experiment, however, only shows the force with which the air tends to expand; for, being confined, there is little real expansion. But the same apparatus will serve for a more striking experiment : let the phial be about half filled with water, and let the tube just enter through the cork. Thus prepared, place the end of the tube into a vessel containing some water, so that the phial may be uppermost ; pour now some hot water upon the phial, and the air in it will be so expanded as to force the water wholly out of the phial, and likely a portion of itself also will escape. Allow the apparatus to remain in the same position until it cools down to its original temperature, when it will be found that the phial contains at least as much water as at first, showing that the air has returned to its original bulk.



As there is no cohesion to overcome in the expansion of gaseous bodies, it may be anticipated that their rates of expansion will be uniform, and that they will all undergo the same degrees of dilatation with the same degrees of heat : this is found by experiment to be true of air, hydrogen gas, steam and vapour of sulphuric ether, and it has therefore been concluded to be true of all aeriform bodies, and for all temperatures. Air may therefore be taken as the type ; and it has been found by the ingenious investigations of Dr Dalton and Guy Lussac, that 1000 volumes of air, on being heated from the freezing to the boiling point of water, that is 180°, become 1375 volumes. From this it follows, that air, at the freezing point, expands the $\frac{1}{480}$th part of its bulk for every degree of heat : that is

480 cubic inches at 32°, become 481 at 33°
481 . . . . 33° 482 at 34°

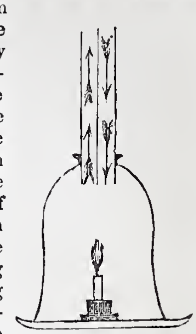
and so on, increasing one cubic inch for every degree. On the same principle, a contraction of one cubic inch occurs for every degree below the freezing point : that is,

480 cubic inches at 32°, become 479 at 31°
479 . . . . 31° 478 at 30°

and so on. From this law, it is easy to deduce the expansion of a volume of gas ef a given temperature by heating it up to any other particular temperature.

What has been said of the conveyance of heat through liquids, applies more emphatically to gaseous bodies from their greater expansibility. Every one has observed "the motes in a sunbeam," and the rapidity with which the ascending and descending currents of air upon which they are borne intermingle : and on heating any body—a poker for instance—and looking across it, the ascent of a heated column of air will be clearly detected. It is the force of this ascending current, which gives the tapering form to the flame of a candle : this consists of aeriform matter in a state of ignition. The fire balloon illustrates the same principle : this is simply a bag formed of some light material, as tissue paper, having its aperture inverted over the flame of a piece of sponge steeped in spirit of wine. It was in dependence, upon this principle, and with such an apparatus, that Rosier first committed himself to float upon the atmosphere.

Some interesting properties of aerial currents may be illustrated, by placing a lighted taper on a flat dish, and covering it by a bell glass, with a long chimney immediately over the flame. A very little water poured upon the dish will prevent the air from entering round the edges of the glass. On this first trial, the taper will speedily be extinguished for want of air, notwithstanding that the chimney is open above it. If, however, the taper be again lighted, and the chimney of the bell glass be divided into two channels, by a diaphragm down the middle and again placed over the taper, it will continue to burn for any length of time. The heated and light particles of air which tended to ascend in the tube in the former arrangement, but were impeded by the opposite tendency of the cold particles to descend, will pass out in an ascending current on one side of the diaphragm, while a contrary current of fresh air will continually compensate them on the other side ; the direction of these currents is rendered visible, by mingling some smoky substance with the descending current. This separation of contrary currents is of considerable importance in the ventilation of mines, and many deep shafts are divided by boarded partitions to ensure the descent of fresh air upon this principle.



We are indebted to the expansion of air for the ventilation of our rooms, and for the ascending currents of our chimneys, by which our fires are maintained. If we hold the flame of a candle to the upper part of a door, opening into a heated room, we shall not fail to find, by the direction in which it is bent, that a current of light air passes outward ; while, by lowering it near the bottom, we shall be able to detect a counter current of denser cold air rushing inward with equal velocity.* The knowledge of these facts, and the principle upon which they depend, ought to lead to a more effectual system of ventilation in our public buildings and factories. In heating an apartment with hot air for instance, the hot air should be introduced at the floor, and the admission of fresh cold air should be at the ceiling. But the well beaten road of routine practice is generally followed, and who is to blame ? Even in our own little dwellinghouses, in defiance of philosophy, common sense, and experience, we often see the under sash of a window thrown up to ventilate a room, instead of the upper sash being drawn down, and for no other reason, than a definition of indolence would suggest.

The distribution of heat is a process of the utmost consequence in some of the grand operations of nature, and it is principally by the circulation of fluids, elastic and non-elastic, that it is effected. The atmosphere is the grand vehicle of distribution, withdrawing heat from one part, where the surface of the earth is exposed to the scorching rays of a vertical sun, and wafting it away to colder climates, to mitigate the extremes of the seasons there. The process is this :—when the surface becomes heated, the stratum of air reposing upon it is expanded and ascends ; its place is supplied by denser air pressing in from colder latitudes, and by a constant succession of these operations, the heat is moderated, which otherwise would be intense, and the constantly ascending warm air, in its effort to sustain the equilibrium of the general mass, must flow on to supply the place of the dense air withdrawn from the colder regions. In the atmosphere, there are therefore always two grand currents—the cold air flowing from the polar regions upon the surface of the earth, and the opposite currents from the equator to the poles, in the upper region of the atmosphere. These compensating currents are no doubt modified by local and partial causes—the inconstancy of the wind has passed to a proverb ; but taking them on their grand scale, they are like all natural effects, based on a general principle, certain and regular as the revolution of the earth itself.

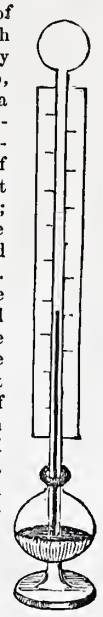
## § 2. Of Thermometers.

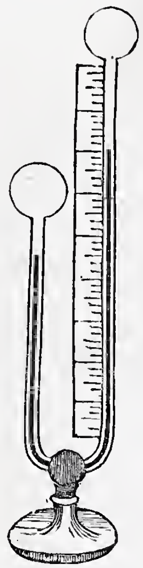
The perfection of science depends upon accurate measurement, but we can neither weigh heat, nor measure its bulk ; and although our sense of touch were a correct judge of the matter, which it is not, we dare not touch things that are very hot or cold ; it therefore becomes necessary to have some artificial means of estimating the presence in bodies of this subtile principle. The influence of heat over the bulk of bodies offers this means—for substances not only expand more and more as the temperature increases, but in general return exactly to the

* Daniel's Chemical Philosophy

original volume, when the heat is withdrawn. Any substance so circumstanced as to allow this expansion to be accurately measured, becomes to us a *thermometer* or measure of heat (from the Greek words *thermos*, signifying *heat* or *fire;* and *metron*, a *measure*.)

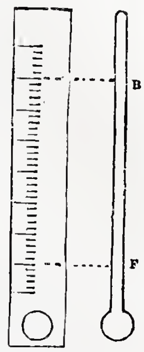
The first attempt to measure the intensity of heat, on this principle, was made early in the 17th century, and the honour of the invention is usually ascribed to an Italian physician, named Santorio, though many maintain that it is due to Drebbel, a Dutch physician, and others award it to the celebrated Galileo. Be this as it may, the instrument, from its imperfect construction, was of little use. It consisted of a phial like that already described, containing a coloured liquid; a long glass tube having a bulb blown at one end, the other extremity being open and plunged into the coloured liquid; and a scale of equal parts. Heat was applied to the bulb to expel a part of the air, which permitted a portion of the coloured liquid to rise in the tube: this fluid column indicates the slightest change of temperature. The heat of the hand, for instance, applied to the bulb, will make it descend rapidly, by increasing the elastic force of the air within the bulb, and causing it to press upon the liquid in the tube. The apparatus of the phial and tube already described, when the phial is about half filled with liquid, and the tube pushed through the cork some way into the liquid, is exactly of the same nature, and serves the purpose of a thermometer just as well: it is in fact Boyle's improved weatherglass. Both are liable to the same objections: they are not capable of measuring variations of temperature through any considerable range, and they are liable to be affected, not only by heat and cold, but by the varying pressure of the atmosphere. Notwithstanding these defects of the *air thermometer*, a very useful modification of it was contrived by Sir John Leslie, which is now known by the name of the *differential thermometer*. This consists of two glass bulbs connected by a glass tube, as represented in the figure.* If both the bulbs be exposed to the same temperature, the instrument of course gives no indication; but if one of the bulbs, the upper bulb for instance, be exposed to a higher temperature than the other, then the air in that bulb is expanded, and the column of liquid is depressed. It is therefore the difference of temperature between the two bulbs which is indicated by the instrument: it is of no use for any other purpose. We shall subsequently see however that it is an instrument of great importance, especially for experiments on radiant heat.





The too great expansion of gases, and the too minute expansion of solids, render both these classes of bodies inconvenient for the construction of thermometers. But liquids fortunately are intermediate in their expansions, and consequently among them we must search for the material best suited to the purpose. The principle of the selection is plain. A material is required whose expansions are uniform, and whose boiling and freezing points are very remote from each other. Mercury, as we have already seen, fulfils these conditions better than any other liquid. No fluid can support a greater degree of heat without boiling than mercury, and there are only a few, as alcohol (spirit of wine), and ether, which can endure a more intense cold without freezing. It has besides the additional advantage of being more sensible to the action of heat than others, being a good conductor, and its dilatations between freezing and boiling points of water are almost perfectly uniform.

A common thermometer consists of a tube terminated at one end by a bulb, blown either of a globular or cylindrical shape, (the latter is the best,) and having the other end *hermetically sealed;* that is, its orifice closed by melting the glass after the introduction of as much mercury as fills the bulb and a small part of the stem. When this instrument is plunged into a hot liquid, the mercury expands and of course *rises* in the tube; on the contrary, when it is plunged into a cold liquid, the mercury contracts, and of course *falls* in the tube. The rising of the mercury indicates increase of heat; its falling a diminution of it; and the quantity which it rises and falls, indicates the proportion of increase or diminution. But in order to render such an instrument of use, it must be provided with a scale of equal parts—a scale on which to measure the amount of expansion, and consequently, the variations of temperature; for expansion and heat may be regarded as convertible terms. The first consideration, in forming such a scale, is manifestly to find out one or more points by which to regulate the graduation. Now, when the important fact is known that solid water or ice melts in every case, at precisely the same temperature, and that pure liquid water in a metallic vessel, and under a given atmospheric pressure; that is, when the mercury in the barometer stands at some particular height, as $29\frac{1}{2}$ inches, boils always at the same temperature, it follows, that by placing such a thermometer in melting ice, and then in boiling water, and marking upon the stem the two points, (F and B) at which the mercury stands, two fixed or invariable points will be obtained; and the interval between them may be divided (either upon the glass, or upon a suitable scale attached to the glass,) into any convenient number of parts, to be called *degrees*. The scale may be extended farther, by continuing the divisions to any extent both above and below the fixed points; the practical limits are the boiling and freezing points of the liquid employed.



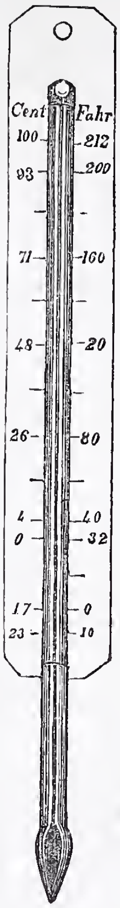

It is to be lamented that different writers have not agreed upon the manner of dividing this invariable quantity, and accordingly, we have various thermometric scales—in other words, philosophers have not agreed as to what amount of expansion should denote a degree of heat. In the scale proposed by Celsius, now very generally adopted on the continent, the space between the two points is divided into 100 equal parts; in Reaumur's scale, which is now falling somewhat into disuse, the same space is divided into 80; and in Fahrenheit's scale, which is that commonly used in this country, it is divided into 180 parts. In Fahrenheit's, however, the freezing point is not, as in the others named, marked 0, because the maker imagined that, by mixing snow and common salt together, he had obtained the lowest temperature possible; and having introduced his thermometer into such a mixture, he observed that the mercury descended lower in the tube, by 32 degrees of his scale; this point he therefore marked 0, and the point at which water freezes, or ice melts, is consequently marked 32°. This arrangement makes the boiling point of water, 212°; that is, the sum of 180° and 32°. This scale though founded on error, has, however, two advantages:—1st. The degrees are small, and therefore it is not so often necessary to express fractional parts, as it is in making observations with the other scales. 2nd. As the degrees below 0, must be distinguished in writing, from those above that point, by some particular mark, and as the 0 of Fahrenheit, is placed at so low a temperature, it rarely becomes necessary to have recourse to any artifice of this kind. When it is necessary to mark degrees of contraction below 0, the negative sign (—), is prefixed, and degrees marked with this sign are termed negative degrees, to distinguish them from degrees above 0, or positive degrees, of the same number. Thus, 39°, means the 39th degree above *zero*, whereas, — 39°, means the 39th degree below *zero*.

In constructing a thermometer, the first requisite is, that the bore of the tube shall be perfectly uniform. If this be not attended to, it is obvious that the real value of the expansion of the mercury will not be shown by a scale of equal parts; and the thermometer, if constructed by the method described, would of course give erroneous indications. To ascertain the uniformity of the tube, it is only necessary to find that a small quantity of mercury, moved up and down in it, occupies exactly the same length at every part; if this is not the case, the tube ought to be rejected. The same method may be taken to ascertain the

* The form here shown is that introduced by Dr. Howard; it is more convenient than the form employed in the original invention, where the bulbs are made to stand both at the same height.

accuracy of a thermometer after it is constructed; and indeed, ought invariably to be applied before purchasing such an instrument. It is to be observed, however, that owing to the extreme difficulty there is in procuring tubes which are absolutely true, a thermometer that is perfectly correct, is too valuable an article to expect at a trifling cost.

Whatever be the external form given to thermometers, or whatever scale be adopted, they are in principle essentially the same. That shown in the figure, where the bulb and stem extend a considerable way beyond the scale, is a very convenient form for chemists, as it may be plunged sufficiently far into liquids, without injuring the scale, which is usually ivory.* The engraving shows the relation of Fahrenheit's scale with the centigrade, the name commonly given to Celsius' scale, because it is divided into 100 degrees between the freezing and boiling points of water. The rule for converting the degrees of the one scale into those of the other, is very simple; 100° Cent., being equal to 180° Fahr.; these numbers have the same relation to each other, that 5 has to 9, that is, 5° Cent.=9° Fahr.; therefore, multiplying the centigrade degrees by 9, dividing by 5, and adding 32°, will be the result required. Thus, suppose that it is required to find what degree of Fahr. corresponds to 40° Cent.? Here, 9 times 40° makes 360°, and the fifth part of 360° is 72°, which increased by 32°, gives 104°, as the equivalent on Fahr.†

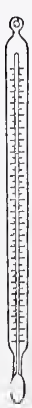



Many other modes of dividing thermometric scales have been proposed, used, disused, and forgotten. That of De Lisle is still used in Russia, which it perhaps suits well, being adapted to measure degrees of *cold;* the boiling point of water is *zero*, and the freezing point is 150°. We must forgive the Czar for tolerating such a scale: he and his boors still reckon time by the old style.

The mercurial thermometer above explained enables us to measure temperatures between —39° and 600°; at the former temperature, mercury becomes solid; at the latter, it begins to rise in the tube in a state of vapour, and to derange the indications, though its boiling point is still about 60° higher. In very low temperatures, therefore, it is necessary to have recourse to alcohol (spirits of wine), which has never yet been frozen, though it has been subjected to a temperature as low as —135° Fahr. How far beneath this lies the *real zero* of heat, or the point at which bodies contain no heat, is beyond our researches. Indeed, the scale of temperature may be compared to a chain extending both ways beyond our sight; we fix upon a particular link, and count upward and downward from that link, and not from the beginning of the chain, of which we know nothing. To ascertain those higher gradations of the chain within our reach, and which mercury will not measure, we have recourse to the expansion of solids.‡ The instruments constructed for this purpose, are called *pyrometers*, (from *pyr*, fire, and *metron*, measure); among the only valuable of which is that of Daniel. The indications of this instrument result from the difference in expansion by heat, of an iron or platinum bar, and a tube of well-baked black-lead ware, in which the bar is contained. The metallic bar A is shorter than the tube into which it fits, and a short plug of earthen ware, B, is placed in the mouth of the tube above the metallic bar. This is called the *index*, and is secured in its place by a strap of platinum foil, and a little wedge, so that it slides with difficulty in the tube. By the expansion of the metallic bar, the plug of earthen ware is pushed outwards, and remains in its new position after the contraction of the metallic bar again by cooling. What now remains is, to find out, by measurement, the distance which the index has been thrown forward. This is done with great precision by a scale adapted to the purpose, but which has nothing very peculiar in the mechanism; the displaced index is brought to bear on the short end of a lever, and the amount of displacement magnified 10 times, is read off upon a circular scale, which is traversed by the long end of the lever. The degrees are convertible into those of Fahrenheit, and the following are some of the temperatures determined by the instrument:—


| | |
|---|---|
| Red heat, - - - | 980° Fahr. |
| Heat of a common fire, - | 1141° |
| Brass melts at - - - | 1869° |
| Silver melts at - - - | 2233° |
| Cast iron melts at - | 2786° |
| Highest heat of a wind furnace, | 3300° |

* There is a still more convenient form in which the thermometer is enclosed in a glass tube—the lower end of the tube being joined to the upper part of the bulb by means of the blow-pipe—as shown in the accompanying figure. This form of the instrument allows of its being passed through a cork or the like, and placed in a liquid during distillation or any similar process, without risk of destroying the scale, which is enclosed in the glass tube, and sometimes engraved upon the glass itself. Thermometers of this construction are almost universally used for chemical purposes upon the continent, and they may be had in Glasgow, of German manufacture, from Messrs. Griffin and Co., at prices varying from six shillings to eighteen shillings, according to the range of the scale.—*See Griffin's Descriptive Catalogue of Chemical Apparatus*, page 57.



† All the rules usually given for converting the degrees of Fahrenheit into Centigrade and Reaumur, and *vice versa*, are comprised in the following formula:—

$$\tfrac{1}{9}\,(\text{F.}^\circ-32)=\tfrac{1}{5}\,\text{C.}^\circ=\tfrac{1}{4}\,\text{R.}^\circ$$

‡ The once famous pyrometer of Wedgwood depends upon exactly the reverse property, namely, upon the property which clay, a compound of alumina and water, possesses, of gradually losing its water when exposed to an increasing temperature, and of contracting as the water is dissipated. It is not now used for any scientific purpose.

# MATHEMATICS.

## CHAPTER III.

### MULTIPLICATION OF NUMBERS.

1. We have already explained (chap. ii. p. 44), that multiplication of numbers is simply a short method of performing addition when it is required to find the sum of a quantity repeated a definite number of times. Thus supposing there are 7 heaps of pebbles, and 23 pebbles in each heap, and it is required to find out how many pebbles there are in all, we would put the following question—what is 23 counted 7 times; in other words, what is 23 *multiplied* by 7? To answer this question, it is obviously enough to write 23 seven times, and make the addition as in the margin, which gives 161 as the sum. In this question, 161 is called the *product* of 7 and 23, and 7 and 23 are the *factors* of that product. Again, 23 is called the *multiplicand*, and 7 the *multiplier;* and in all cases where a product is found, the operation is called *multiplication*.

$$\begin{array}{r} 23 \\ 23 \\ 23 \\ 23 \\ 23 \\ 23 \\ 23 \\ \hline 161 \end{array}$$

Were there no questions in arithmetic more difficult than this, then there would be little occasion for any shorter method than that shown above. But if there were 2767 heaps of pebbles, and 8967 in each heap, it is evident that the labour of addition would be quite intolerable: we would require to write 8967 two thousand seven hundred and sixty-seven times, and add up the enormous columns. Accordingly, multiplication has been invented to shorten the process by separating it into a certain number of partial operations which may all be performed with facility.

We have already found in addition, that it is only necessary to find any sum however great, to be able to assign with readiness the sum of any numbers under 10; so similarly in multiplication, the chief difficulty to be surmounted is the learning of the products of all numbers under 10, that is up to 9 times 9 inclusive. These products are shown in the following table, all the part of which cut off by the bold black lines, it is *absolutely necessary to commit accurately to memory*, and it will be highly advisable to learn the whole.

TABLE.

| Multiplicands | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Multipliers. | Products. | | | | | | | | | | |
| 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 |
| 3 | 6 | 9 | 12 | 15 | 18 | 21 | 24 | 27 | 30 | 33 | 36 |
| 4 | 8 | 12 | 16 | 20 | 24 | 28 | 32 | 36 | 40 | 44 | 48 |
| 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 |
| 6 | 12 | 18 | 24 | 30 | 36 | 42 | 48 | 54 | 60 | 66 | 72 |
| 7 | 14 | 21 | 28 | 35 | 42 | 49 | 56 | 63 | 70 | 77 | 84 |
| 8 | 16 | 24 | 32 | 40 | 48 | 56 | 64 | 72 | 80 | 88 | 96 |
| 9 | 18 | 27 | 36 | 45 | 54 | 63 | 72 | 81 | 90 | 99 | 108 |
| 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | 110 | 120 |
| 11 | 22 | 33 | 44 | 55 | 66 | 77 | 88 | 99 | 110 | 121 | 132 |
| 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 | 132 | 144 |

The second horizontal line of this table contains the products of the numbers of the first line by 2, the third line their products by 3, and so on. All the products in the table may be readily found by addition, and perhaps the easiest way of learning them is for the student to make the table several times over for himself by addition: he will find the work more interesting, and he will understand its nature better than by conning over the dry numbers of the printed table. He will also observe certain relations among the products of certain of the multipliers which will help him considerably; for instance all the products by 5 terminate in 5 and 0 alternately; and in the successive products by 9, the first figure increases, and the second decreases by 1 each time. We are aware however that the task with all the facilities that can be thought of is tedious and dry, and requires some perseverance.

2. When we observe closely the construction of the foregoing table, we find that the product of 5 by 7, is the same as the product of 7 by 5; the product in both instances is 35. The same observation may be made with regard to other numbers contained in the table; and hence we conclude that in any case of multiplication we may invert the order of the *factors;* that is to say, take the multiplier for the multiplicand, and the multiplicand for the multiplier.

This may be shown in the following manner, where it is to be observed that we use the sign $\times$ to mean *multiplied by* and write the multiplicand on the left of the sign, and the multiplier on the right. The assertion is that

$$5 \times 7 = 7 \times 5.$$

Now it is obvious from the nature of multiplication as already explained, that $5 \times 7$ means nothing more than $1 + 1 + 1 + 1 + 1$ repeated 7 times, and that it is sufficient for the performance of the operation to take each unit 7 times, so that

$$5 \times 7 = 7 + 7 + 7 + 7 + 7 = 35.$$

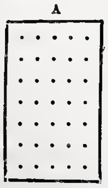
And again $7 \times 5$ means $1 + 1 + 1 + 1 + 1 + 1 + 1$ repeated 5 times, so that

$$7 \times 5 = 5 + 5 + 5 + 5 + 5 + 5 + 5 = 35.$$

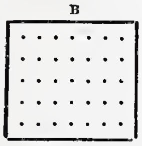
And therefore we conclude, since there is nothing to induce us to take one pair of factors rather than another, that the proposition is generally true.

The same reasoning may be represented under the following form.

A



B



Placing 5 counters in a line, and repeating that line in all 7 times, the number of counters in all is 7 times 5, forming table A; but by reversing this table, we obtain table B with 7 counters in each line, and that line repeated 5 times; the number in both tables is obviously and necessarily the same. The same method may be applied to any other two numbers.

From the foregoing reasoning it therefore follows, that in finding the product of two numbers (and all cases of multiplication may be reduced to that operation), we may take for the multiplier whichever of the numbers we please.

3. We have already assumed as a thing requiring no special roof that $5 \times 7$ means $1 + 1 + 1 + 1 + 1$ repeated 7 times; and certainly no proof is required in this, or in cases similarly within the immediate comprehension of the mind. But this is the fundamental principle upon which the rule for multiplication depends, and may be stated thus:—

*Any quantity is multiplied by any number, when every one of its parts is taken as many times as there are units in the multiplier.*

This is plain without any special proof, on considering that a sum of money will be increased twenty-fold, if every shilling of it be replaced by 20 shillings; and a quantity of grain will be doubled by doubling every bushel or every quarter of it. This being understood, we shall now proceed to apply it to a particular case.

Multiply 7834 by 6, that is, find $7834 \times 6$. Here the multiplicand at full length is

7 thousands, 8 hundreds, 3 tens, and 4 units.

Now each of these parts being multiplied by 6 will be the product of 7834 and 6, and the result is

42 thousands, 48 hundreds, 18 tens, and 24 units.

The remaining part of the operation is to reduce the result to the ordinary order: to do this

| | |
|---|---|
| 24 units may be put down. . | 24 |
| 18 tens, . . . . . | 180 |
| 48 hundreds, . . . . | 4800 |
| 42 thousands, . . . . | 42000 |

and adding together these partial results we get 47004 as the product of 7834 and 6, that is, $7834 \times 6 = 47004$.

The following instances may be worked in the same way.

$756 \times 7 = 5292$ $\quad 7289 \times 6 = 43734$ $\quad 4756 \times 8 = 38048.$

As it would be troublesome to proceed with every case in the analytic way shown above, we avail ourselves of the principle without being at the trouble of writing the process at full length. An example will make the method plain. Suppose we want to multiply 56384 by 7. Write the multiplicand and multiplier as in the margin

$$\begin{array}{r} 56384 \\ 7 \\ \hline 394688 \end{array}$$

Then $4 \times 7 = 28$, put down 8 and carry 2.

$8 \times 7 = 56$, and 2 carried make 58; put down 8 and carry 5.

$3 \times 7 = 21$, and 5 carried make 26; put down 6 and carry 2.

$6 \times 7 = 42$, and 2 carried make 44; put down 4 and carry 4.

$5 \times 7 = 35$, and 4 carried make 39, which put down.

From this then it appears, that when the multiplier contains only one figure the rule is,

*Multiply each figure of the multiplicand by the multiplier commencing at the right; and in so doing write down the right hand figure of each partial product immediately underneath the figure which gives it, and add the left hand figure to the next similar product: the last partial product is of course to be written down in full.*

The following are instances of the application of this rule:—

$$\begin{array}{r} 36784675679 \\ 7 \\ \hline 257492729753 \end{array} \qquad \begin{array}{r} 353643896734 \\ 9 \\ \hline 3182795070606 \end{array}$$

As explained in addition, the operation may be commenced at the left, and the carriage figures written down and afterwards added. The example in the margin is sufficient to render this plain. This method has its advantages, though it is certainly wanting in neatness, when compared with the ordinary mode shown in the preceding examples.

$$\begin{array}{l} 6483675 \\ 6 \\ \hline 36488620 \\ \ \ 241343 \\ \hline 38902050 \end{array}$$

4. It is evident that when the multiplicand is terminated by one or more ciphers, the operation ought to begin only at the first significant figure; but to give the product the value which it ought to have, we must place on the right of it as many ciphers as the multiplicand contains. When ciphers are contained among the figures of the multiplicand, they yield no product, for 0 multiplied by any number however great is 0. We ought therefore consequently to write 0 when such a case occurs, unless there be some carriage to be added at the place. The remarks are exemplified in the operation on the margin.

$$\begin{array}{r} 30067000 \\ 7 \\ \hline 210469000 \end{array}$$

We have already shown that a number is increased tenfold by every cipher placed on the right of it. But this is only another way of saying that a number is multiplied by 10, by annexing a cipher to it; by 100, when two ciphers are annexed; by 1000, when three ciphers are annexed, and so forth. Thus, 10 times 428, is 4280; for 428 is

4 hundreds, 2 tens, and 8 units.

and taking each of these parts ten times, which is the same as multiplying the whole by 10, we get

40 hundreds, 20 tens, and 80 units,

But this is equivalent to

4 thousands, 2 hundreds, 8 tens, and 0 units,

that is, 4280. In the same way we satisfy ourselves of the truth of the other cases; but the whole is rendered obvious enough by the instances in the following table:—

| | |
|---|---|
| $12 \times 10 = 120$ | $120 \times 10 = 1200$ |
| $12 \times 100 = 1200$ | $100 \times 100 = 10000$ |
| $12 \times 1000 = 12000$ | $3010 \times 1000 = 3010000$ |
| $12 \times 10000 = 120000$ | $100000 \times 10000 = 1000000000$ |

This enables us when the significant figure is different from 1, as when the multiplier is 40, 400, 4000, &c., to resolve the operation into two others. For, understanding that 40 is $4 \times 10$, that 400 is $4 \times 100$, and so on, we may first multiply by the significant figure, and then annex the ciphers of the multiplier to the product. To take an example, let it be required to multiply 864 by 400. The operation may be arranged in either of the following modes:—

```
864            864
400              400
------         ------
345600         345600
```

The four significant figures of this product result from the multiplication of 864 by 4; and in the first arrangement of the process, they are removed two places towards the left, to leave room for the two ciphers which terminate the multiplier. We may state the process thus:—When the multiplier is followed by any number of ciphers, we first multiply the multiplicand by the significant figure of the multiplier, and then write on the right of the product as many ciphers as there are in the multiplier.

5. The preceding is only a particular case of the following:—*To multiply by any number, we may multiply separately by any parts into which we may choose to divide the number, and add the results.*

Suppose it is required to multiply 1061306 by 2134; since 2134 is made up of 2000, 100, 30, and 4, we may multiply 1061306 by each of these parts, and add the products which we get.

```
Now, 1061306 ×    4 is    4245224
     1061306 ×   30 is   31839180
     1061306 ×  100 is  106130600
     1061306 × 2000 is 2122612000
                       ----------
     The sum of these is 2264827004
```

and this is the product sought.

As the ciphers on the right of the partial products are of no value in the addition, it is obvious that they might be omitted, provided we keep the other figures in their respective places. But we observe that were we to cancel the ciphers, the second line would be one place to the left of the first; the third one place to the left of the second, and so on; that is, the first figure of the product from the tens of the multiplier will fall under the tens of the product by the units; the first figure of the product, by the hundreds of the multiplier, will fall under the hundreds' place of the units' product, and so on. Consequently, this being borne in mind, we might multiply the multiplicand by the successive figures of the multiplier, arranging the partial products in this way, without the trouble of decomposing the multiplier into parts at all. The preceding question is shown according to this abridged method in the margin; where it will be observed that the figures of the same *local* values, that is, units, tens, hundreds, &c., all stand under one another.

```
   1061306
      2134
----------
   4245224  prod. by 4
  3183918   prod. by 3
 1061306    prod. by 1
2122612     prod. by 2
----------
2264827004
```

This leads to the following general rule for multiplication:—

I. *Write down the multiplicand, and beneath it the multiplier, so that units may be under units, tens under tens, and so on, and draw a line so as to separate these numbers from the product.*

II. *Multiply each figure of the multiplicand by each figure of the multiplier, as directed in Art. 3, taking care to place the first figure of each successive product under the figure of the multiplier from which it arises.*

III. *Add together the several partial products, and the result will be the product sought.*

The following examples may be compared with this rule.

```
    3426           1300214           5554444
    6234              1234              9765
--------       -----------       -----------
   13704           5200856          27772220
  10278           3900642          33326664
  6852           2600428          38881108
20556            1300214          49989996
--------       -----------       -----------
21357684        1604464076       54239145660
```

When ciphers occur at the end of both multiplicand and multiplier, they may of course be all neglected until the product of the significant figures is found, when they are to be annexed. Thus, supposing we are to multiply together 789000, and 49600, we first find the product of 789 and 496, which is 391344; then five ciphers annexed to this product, give 39134400000, the product sought.

6. When there are ciphers intermixed with the figures of the multiplier, the case is not more difficult, when the nature of the process is thoroughly understood. The following example will show that the rule is a sufficient direction here as before:—

Multiply 1234 by 1002001.

Here $1002001 = 1000000 + 2000 + 1$.

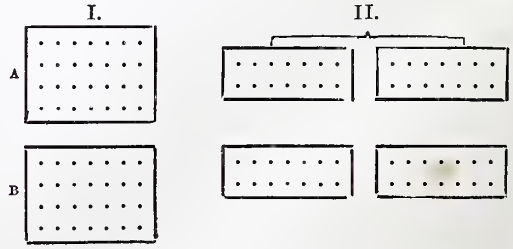
```
Then 1234 × 1       is       1234
     1234 × 2000    is    2468000
     1234 × 1000000 is 1234000000
                       ----------
The sum of which is    1236469234
```

And, arranging the question, and neglecting the ciphers on the right of the products as before, the operation resolves itself into the annexed form, where it will be observed, that the first figure of each partial product is placed immediately under the figure of the multiplier from which it results.

```
      1234
   1002001
----------
      1234
   2468
1234
----------
1236469234
```

7. There is another way in which numbers may be multiplied together. Since 8 is 4 times 2, 7 times 8 may be made by multiplying 7 and 4, and then multiplying that *product* by 2. To show this, place 7 counters in a line, and repeat that line in all 8 times, as in figures I. and II.

I. II.




The number of counters in all is 8 times 7, or 56. But (as in fig. I.) enclose each four rows in oblong figures, such as A and B, the number in each oblong is 4 times 7, or 28, and there are two of these oblongs; so that, in the whole, the number of counters is twice 28, or $28 \times 2$, or 7 first multiplied by 4, and that product by 2. In fig. II., it is shown that 7 is multiplied by 2, and that product by 4. The same method may be applied to other numbers. Thus, since 72 is 8 times 9, then will 72 times 789 be 8 times 789, and that product multiplied by 9. If we use the signs, the foregoing assertions will stand thus:—

$$7\times 8 = 7\times 4\times 2 = 7\times 2\times 4.$$
$$789\times 72 = 789\times 8\times 9 = 789\times 9\times 8.^{*}$$

This principle will be found of great use hereafter: it is the foundation of the common rule for multiplying by *composite numbers;* that is, for numbers composed of two or more factors, as $15=3\times 5$; $21=7\times 3$; $45=9\times 5$, &c., shown in the multiplication table. The rule is stated thus:—Multiply the multiplicand by one of the factors of the composite number, and the successive products by the other factors.

Multiply 7964 by 48. According to the table 48 is $6\times 8$, or $4\times 12$, therefore

$$7964\times 48 \begin{cases} \text{is } 7964\times 6\times 8 = 47784\times 8 = 382272 \\ \text{or } 7964\times 4\times 12 = 31856\times 12 = 382272 \end{cases}$$

Similarly,

$$382272\times 12 = 1529088\times 3 = 4587264$$
$$4785\times 14 = 33495\times 2 = 66990$$

8. The method here suggested is not confined to composite numbers, but may be extended to all numbers whatever. For if the factors of a composite number, a little greater or less than the multiplier, are known, then might we proceed in this way:—Multiply by the factors of that composite number as before, and increase or diminish the last product, according as the composite number is less or greater than the multiplier, by the product of their difference into the multiplicand—the result will evidently be the product of the multiplicand by the multiplier.

Suppose it required to multiply 7964 by 57.

| 1st. Since $57=7\times 8+1$. | 2d. Since $57=10\times 6-3$. |
|---|---|
| 7964 | 7964 |
| 7 | 10 |
| 55748 | 79640 |
| 8 | 6 |
| Add $\begin{cases} 445984 = 7964\times 56 \\ 7964 = 7964\times 1 \end{cases}$ | From $477840 = 7964\times 60$<br>Take $23892 = 7964\times 3$ |
| $453948 = 7964\times 57$ | $453948 = 7964\times 57$ |

The method shown here is very convenient when the multiplier is small; but when it is very large, we must, for the sake of further convenience, modify the rule so as to be applicable upon a mere knowledge of the general composition of numbers. Thus, suppose we are required to multiply 7964 by itself, that is to find $7964\times 7964$.

Since $7964 = 7000+900+60+4 = 7\times 1000+9\times 100+6\times 10+4$.

| | | | |
|---|---|---|---|
| | $7964\times 4 =$ | $31856 =$ | 4 times |
| | 10 | | |
| 10 times | $79640\times 6 =$ | $477840 =$ | 60 times |
| | 10 | | |
| 100 times | $796400\times 9 =$ | $7167600 =$ | 900 times |
| | 10 | | |
| 1000 times | $7964000\times 7 =$ | $55748000 =$ | 7000 times |

The sum of these $= 63425296 = 7964$ times.

This process, which is applicable to all numbers however great, may be translated into the following rule:—

*Multiply the given number by* 10, *the product by* 10, *and so on, as often as there are figures in the multiplier* less one. *Multiply the given number by the units of the multiplier—the first product, or* 10 *times the given number, by the tens—the second product, or* 100 *times the given number, by the hundreds, and so on. The sum of these products being the sum of the products of the multiplicand by the units, by the tens, then hundreds, &c., of the multiplier, must evidently be the product of the multiplicand by the multiplier.*

This method is important, chiefly from the application hereafter to be made of it; but, in the mean time, we recommend the student to use it as a check on the operation by the ordinary rule; that is, as a mode of proving the accuracy of his work by trying whether his results agree when obtained by both methods.

* We are indebted for the illustration given here to Professor De Morgan's Elements of Arithmetic, the best work of the kind with which we are acquainted.

He will find this of great use from the additional illustration which the one rule affords of the principles of the other.

9. When any number is multiplied by itself any number of times, the result is called a *power* of the number, the degree of which is marked by the number of factors, and according to the language employed we call the number itself the first power.

| | | |
|---|---|---|
| Thus, 5 is called the | first | power of 5 |
| $5\times 5$ | second | power of 5 |
| $5\times 5\times 5$ | third | power of 5 |
| $5\times 5\times 5\times 5$ | fourth | power of 5 |

and so on. The second and third powers are usually called the *square* and *cube,* from certain connexions with the square and cube in geometry. The following cases will serve as exercises in the multiplication of numbers:—

| Number. | Square. | Cube. |
|---|---|---|
| 125 | 15625 | 1953125 |
| 216 | 46656 | 10077696 |
| 343 | 117649 | 40353607 |
| 512 | 262144 | 134217728 |
| 729 | 531441 | 387420489 |

The fifth power of 36 is 60466176
fourth 44 is 3748096
fourth 889 is 62407283041

There are many ways of forming questions for exercise in this rule; but, perhaps, the following is in the mean time the best:—Take two numbers and multiply each by itself, and subtract the square of the less from the square of the greater; thus, supposing the numbers taken to be 121 and 235,

$$235\times 235 = 55225$$
$$121\times 121 = 14641$$
$$\text{Difference} = 40584$$

Take now the sum and difference of the numbers chosen, and multiply them together: the result should be the same as before.

| | |
|---|---|
| 235 | 235 |
| 121 | 121 |
| Sum = 356 | 114 = difference. |

Then $356\times 114 = 40584$ as before.

In this way any number of exercises may be constructed, all furnishing their own answers.

10. When the factors are very large, it is often convenient to make a table of the products of the multiplicand by the first nine figures; the work is then performed simply by transferring the numbers in the table to their respective places under the multiplier, and finding the sum as in the ordinary rule.

A table of this kind is easily constructed, and involves little risk of error. It may be made wholly by addition; but advantage may be taken of the facility with which a particular line may be doubled to give another. We shall take an example, and indicate on the side of the table how the successive lines are got.

Suppose it required to multiply 2768954837 by 74829536.

TABLE OF MULTIPLICAND.

| | | |
|---|---|---|
| 1 time = | 2768954837 | 1st |
| 2 times = | 5537909674 | 2d = 1st × 2 |
| 3 times = | 8306864511 | 3d = 2d + 1st |
| 4 times = | 11075819348 | 4th = 2d × 2 |
| 5 times = | 13844774185 | 5th = 2d + 3d |
| 6 times = | 16613729022 | 6th = 3d × 2 |
| 7 times = | 19382683859 | 7th = 3d + 4th |
| 8 times = | 22151638696 | 8th = 4th × 2 |
| 9 times = | 24920593533 | 9th = 4th + 5th |

Now, to find the answer to our question, it is only necessary to transfer the lines of this table, which answer to the figures of the multiplier to our operation, and find their sum as usual. We leave the work to the student; but we may inform him that he ought to get for answer 207199605657665632.

It will here be observed that the labour is increased by the foregoing process; but we are often far more than recompensed for the operation of constructing the table by the certainty which it affords. There is often an unpleasant mental exertion attending long operations when the eye has to travel continually

from the multiplier to the multiplicand and product, which are at some distance; this materially increases the risk of errors, and renders it almost always essentially requisite to do the work twice over where the result is important.

## ANATOMY AND PHYSIOLOGY.

### CHAPTER III.

#### THE MUSCLES AND MUSCULAR ACTION.

#### I. *A General Description of the Mechanism and Uses of the Muscles.*

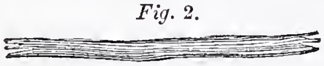
A MUSCLE is composed of long slender fibres, which possess the power of contracting, and are everywhere enveloped in common cellular membranes; the fibres become fewer as they approach the extremity of the muscle, and ultimately terminate. The cellular substance (that envelops them) being thus freed from the muscular fibres joins more closely together, and forms itself into a white round ropy or flattened tendon—when the muscular fibres contract, their power is united on the tendon, and drawing it up, make it perform the action of a pulley. Tendons are therefore composed, not of muscular fibres, but of the cellular substances with which the fibres are enveloped. Every muscle is supplied with arteries, veins, lymphatics, and nerves; for without these they could neither grow, renew, nor contract. Their vital power is derived from their nerves.

Muscles are of two kinds, simple and compound. The simple are called ventriform, when their bellies are large, but diminish in size as they approach their tendons. Fig. 1. They are

*Fig.* 1.

called parallel, when their fibres terminate in a broad fibrous web, without tendons. Fig. 2. They are penniform, when their

*Fig.* 2.

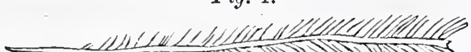


fibres run parallel, but oblique to their tendons, like feathers on one side of a quill. Fig. 3. They are double-penniform when

*Fig.* 3.

two ranges of parallel fibres pass obliquely into a tendon running along their centre. Fig. 4. They are double-bellied where they

*Fig.* 4.

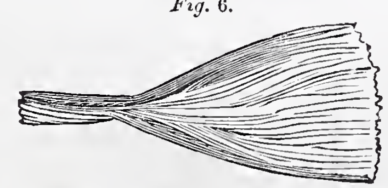


have two bellies meeting, and inserted into one tendon. Fig. 5.

*Fig.* 5.

They are called fan-shaped, when they are broad and thin at the origin, and thick at its insertion into the tendon. Fig. 6. In fishes,

*Fig.* 6.



the muscles are white, in man red; but the blood which makes them red can be washed away.

Different muscles accomplish very different purposes. 1st. They envelop, compress, and sustain, the viscera, or internal organs of the abdomen, or belly. 2d. They lengthen, shorten, or compress, some organ or organs—such as the tongue, &c. 3d. They widen, or contract, some opening,—as the sphincter muscles do, at the entrance of the natural passages of the body. 4th. They roll, or move, the organs of the senses,—such as the eye, ear, &c. 5th. They relax, pull up, or make rigid, a valve, as the epiglotis; a septum, or division of parts, as the velum pendulum palati, or vail of the palate, &c, 6th. When they are inserted, or attached to bones, we perform by their action, locomotion, as walking, running, leaping, dancing, &c. Some of the tendons are flat and broad like a web,—others radiate and spread out into digitations like fingers,—and some are long and round, like cords.

The muscles, especially of the extremities, are, in general, either flexors, extensors, pronators, adductors, abductors, or rotators. The flexors bend, or draw down the limb, or the part to which they are attached, if it has a moveable joint, and are placed under that part of the body on which they act, as antagonists to the extensors. The extensors raise, elevate, and extend, the moveable parts to which they belong, and are placed on the superior surface, as antagonists to the flexors. Some muscles move the parts obliquely, as the oblique muscles of the eye—some make them describe a semicircle, as in the motions of the neck, arms, and legs, &c.—some elevate the parts, as the upper eyelids, &c.; others contract them, as the eyebrows; or corrugate them, as the extremity of the lips—some are abductors, and others adductors, as in the legs, arms, fingers, toes, &c., moving them to either side. Some are supinators, and others pronators, as in the forearm and fingers, &c.—some are transverse, others straight, oblique, or pyramidal, as on the abdomen or belly, &c.—some are erectors, others ejaculators, as in the sexual and seminal organs—some are half-membranous and half-tendinous—as in the legs, &c. In short, muscles are as varied in form as in action, and perfectly adapted to the wise purposes for which the Great Architect of the universe has inimitably formed and designed them, in the sublime and beautiful mechanism of the living animal machine.

#### II. *The Difference betwixt Muscular Power, and Nervous Sensibility.*

The vital power of a muscle resides in the nerves, and is nervous. Its irritable power is the property by which it feels and acts, when stimulated without consciousness. It is an inherent principle, and belongs to its constitution, and remains for some time after death. Ligaments and tendons support the same weight, whether dead or alive; but a living muscle, that lifts 100 lbs. with ease, cannot, after death, raise 20 lbs. without danger of rupture. When a muscle is newly cut from a limb, it palpitates and trembles for a considerable time—it cannot be nervous power that thus makes it irritable; for the nerves being separated from their origin are dead and powerless. If the heart is newly separated from the body, it contracts if irritated The bowels continue their peristaltic motion after death, until they become stiff and cold—even in vegetable life, as in the sensitive plant, this contractile power is visibly exhibited. It is not nervous power; for it belongs absolutely to the muscle, and exists in some cases without nervous vitality altogether—hence there is a distinction betwixt nervous sensibility, and muscular irritability. The former dies immediately with the animal; the latter lives for a short time after the animal is dead. Muscles are irritable and contractile by the inherent principle of their fibres, and are sensible by the vitality communicated through their nerves. Though nerves are sensible, they are not contractile, and cannot perform the functions of muscular fibres.

The muscles are of two kinds—voluntary and involuntary; the heart is stimulated involuntarily by the circulating blood—the stomach by food—the bowels by their contents—the kidneys by urine—the genital system, by sensual appetite—and the womb by its fœtus. But the voluntary muscles are stimulated by the nerves, and obedient to our will—we lift our hands and arms—jump and walk—dance and sing—because we will them. The muscles of these parts are therefore voluntary; but the heart moves without our will, and is therefore an involuntary muscle. The nerves do not move like muscles under the influence of stimuli—they only convey the impressions or commands betwixt

*Fig. 1.*

1. Occipito frontalis.
2. Atollens aurem.
3. Anterior auris.
4. Orbicularis palpebrarum.
5. Compressor naris.
6. Levator anguli oris.
7. Levator labii superioris alæque nasi.
8. Zygomaticus major.
9. Zygomaticus minor
10. Masseter.
11. Depressor anguli oris.
12. Sterno cleido mastoideus.
13. Depressor labii inferioris.
14. Orbicularis oris.
15. Platysma myoides.
16. Extensor digitorum communis.
17. Extensor carpi radialis longior.
18. Extensor carpi radialis brevior.
19. Abductor indicis manus.
20. Deltoides.
21. Biceps brachii.
22. Pronatur radii teres.
23. Supinator radii longus.
24. Flexor carpi ulnaris.
25. Flexor carpi radialis.
26. Palmaris longus.
27. Aponeurosis palmaris.
28. Abductor pollicis manus.
29. Palmaris brevis.
30. Flexor sublimus perforatus.
31. Pectoralis major.
32. Obliquus descendens externus.
33. Linea semilunaris.
34. Linea alba.
35. Poupart's or Fallopius' ligament.
36, 36. Sartorius.
37. Tensor vaginæ femoris.
38. Gracilis.
39. Iliacus internus.
40. Pectinalis.
41. Triceps adductor femoris.
42. Psoas magnus.
43. Vastus externus.
44. Vastus internus.
45. Rectus.
46, 46. Tibialis anticus.
47. Extensor longus digitorum pedis.
48. 48. Extensor proprius pollicis pedis.
49. Malleolus internus.

*Fig. 2.*

1. Corrugator.
2. Temporalis.
3. Masseter.
4. Buccinator.
5. Orbicularis oris.
6. Depressor labii inferioris.
7. Levator anguli oris.
8. Sterno cleido mastoides.
9. Extensor ossis metacarpi pollicis manus.
10. Extensor primi internodii.
11. Extensor secundi internodii.
12. Indicator.
13. Abductor indicis manus.
14. Flexor sublimus perforatus.
15. Lumbricalis.
16. Flexor ossis metacarpi pollicis.
17. Abductor minimi digiti manus.
18. Flexor parvus minimi digiti.
19. Sterno hyoideus.
20. Biceps brachii.
21. Pectoralis minor
22. Serratus magnus.
23. Obliquus ascendens internus.
24. Pyramidalis.
25. Rectus abdominus.
26. Iliacus internus.
27. Psoas magnus.
28. Pectinalis.
29. Triceps adductor femoris.
30. Gracilis.
31. Vastus externus.
32. Cruralis.
33. Vastus internus.
34. Ligamentum patellæ.
35, 35. Extensor proprius pollicis pedis.
36, 36. Extensor longus digitorum pedis
37, 37. Malleolus internus.

*Fig. 3.*

1. Temporalis.
2. Occipito frontalis.
3. Platysma myoides.
4. Sterno cleido mastoideus.
5. Trachelo mastoideus.
6. Splenius.
7. Deltoides.
8. Biceps brachii.
9. Brachialis iuternus.
10. Supinator radii longus.
11. Triceps extensor cubiti.
12. Trapezius seu cucullaris.
13. Latissimus dorsi.
14. Serratus magnus.
15. Obliquus descendeus externus.
16. Gluteus maximus.
17. Gluteus medius.
18. Sartoris.
19. Vastus internus.
20. Vastus exteruus.
21. Rectus.
22. Tendon of the biceps muscle, forming the outer ham-string.
23. Tendons of the semimembranosus, aud semitendinosus muscles, forming the inner ham-string.

24 Gastrocnemius externus.
25, 25. Peroneus brevis.
26. Extensor longus digitorum pedis.
27. Extensor brevis digitorum pedis.
28. Plantaris.
29. Gastrocnemius.
30. Tendo achillis

*Fig 4.*

1. Occipito frontalis.
2. Temporalis.

3, 3. Trapezius seu cucullaris.

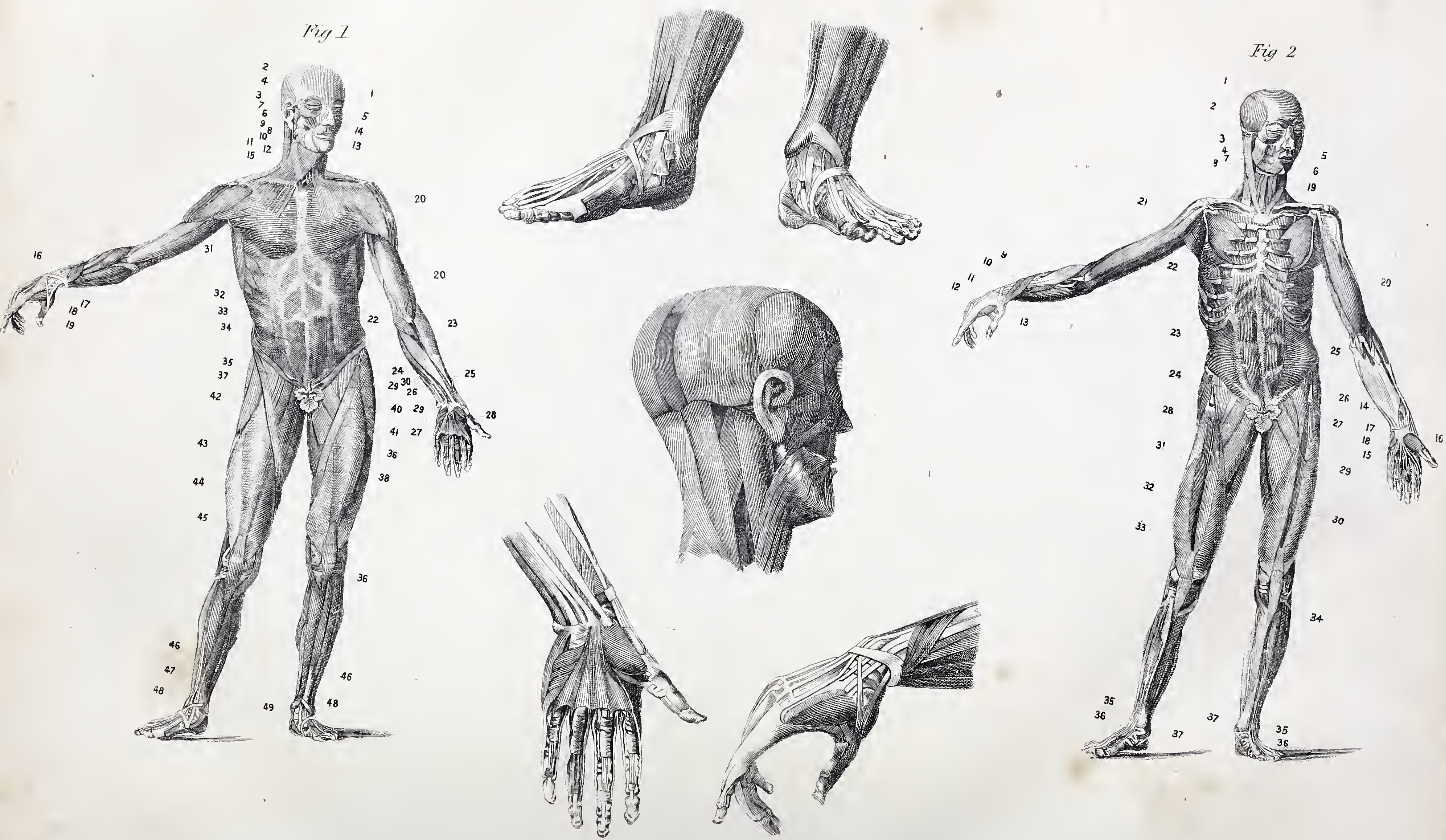
4. Sterno cleido mastoideus.
5. Deltoides.
6. Extensor ossis metacarpi pollicis manus.
7. Extensor primi internodii.
8. Extensor secundi internodii.
9. Extensor digitorum communis.
10. Triceps extensor cubiti.
11. Extensor digitorum communis.
12. Latissimus dorsi.
13. Gluteus maximus.
14. Biceps flexor cruris.
15. Semitendinosus.
16. Semimembranosus.
17. Gastrocnemius.

18, 18. Peroneus brevis.
19, 19. Peroneus longus.
20, 20. Tendo achillis.

*Fig. 5.*

1. Temporalis.
2. Complexus.
3. Splenius.
4. Levator scapulæ.
5. Rhomboideus minor.
6. Supra spinatus.
7. Serratus superior posticus.
8. Rhomboideus major.
9. Infra spinatus.
10. Triceps extensor cubiti.
11. Extensor primi internodii.
12. Extensor secundi internodii.
13. Indicator.
14. Serratus posticus inferior.
15. Gluteus medius.
16. Obliquus ascendens internus.
17. Biceps flexor cruris
18. Semitendinosus.
19. Semimembranosus.
20. Plantaris.

21, 21. Gastrocnemius internus.
22, 22. Gastrocnemius exterius, part cut off.
23, 23. Tempo achillis.




MUSCLES OF THE HUMAN BODY

*Fig 3*

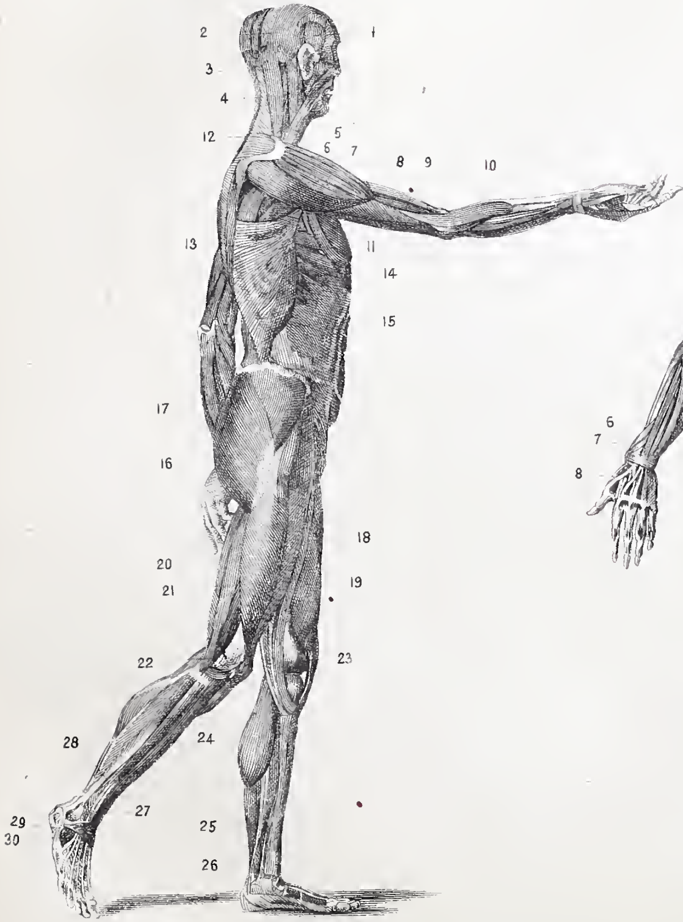


*Fig 4*

*Fig. 5*

MUSCLES OF THE HUMAN BODY

our will and our muscles ; but the muscles alone possess a contractile power, and employ it—nervous power is sometimes exhausted and apt to change ; muscular power is always perfect, and ready to act when stimulated, in obedience to our will—but the muscles soon lose their contractile power, when deprived of sensibility by paralysis of their nerves. The involuntary muscles are mechanically stimulated without our control—the voluntary are put into action by the impulses of the mind, and are under our arbitrary commands. The nerves of feeling and motion in the extremities come from the spinal cord. The muscles of the body are double, and on each side equal in number, action, and power; the muscles on one side balance the muscles on the other. If on one side they are paralyzed, and cannot contract, those on the other, exerting their usual strength, destroy the balance of power—in palsy of one side of the face, this fact is visibly illustrated. If a joint be dislocated, the action of the muscles is violent and spasmodic till it be reduced; nervous influence is therefore the stimulus of the voluntary muscles—mechanical agents stimulate the involuntary. If a man be suddenly killed, the irritable power of his muscles survives his nervous sensibility; for his flesh trembles, and his absorbents continue their function, for a while after he is dead, and his nervous power annihilated. In cases of suffocation, we sometimes restore animation after the nervous sensibility is suspended, and when nothing is left to aid our experiments, but muscular irritability. If putrefaction has commenced, the irritable power of the muscle is for ever gone, and nothing can restore it. Sensibility therefore depends on the nerves—motion on the muscles ; the one conduces to our pleasures and pains, and is connected with our intellect—the other is the prime support of animal life, and the source of corporeal power—yet both are necessary in the living animal, to produce locomotion.

The length of the lever increases the mechanical power of the muscle—the mastoid process laterally, and the occiput posteriorly, are levers for the head—the spine of the vertebræ for the back—the olecranon or elbow for the arm, and the pisiform bone for the hand—the pelvis or basin, and the trochanters of the thighbones, are levers for the thigh—the patella or kneelid for the leg—the heelbone for the foot, and the arch of the foot for the toes. These are the principal, but not all the levers of the body.

In all the other muscular implantations, the ends of the muscles are levers, not behind the joint ; but betwixt the joint and the body to be moved. There is a greater loss of power when they are inserted near a joint, and there is less loss of power, when a tendon is fixed far from a joint; for although such insertions be designated shorter or longer levers—yet there is always some mechanical loss of power, and true levers in the body are very few indeed. Nature has provided as much contractile power in the muscular fibres, as to compensate for the loss in effect of the lessened mechanical power of the levers; and in place of increasing the effect of muscles by levers, pulleys, and hinges, there is in almost every muscle, a great abatement of its force, by the form of the bone it is designed to move ; for muscles lose much of their effect by implantation, not behind the joint, but betwixt the joint and the body to be moved, and their oblique insertion, with regard to the motion about to be performed ; and half their power is lost, on the immovable end of the bone. In the human body, muscular power is always sacrificed to preserve the form and symmetry of the parts, to make the joints smaller than the limbs, and proportion the limbs to the body. Extraordinary lever power is not often required in the motions and actions of the body; for the great Creator has appointed sufficient vital and contractile power in the muscles, to effect every useful purpose, and at the same time preserve the beauty and mechanism of the animal machine, according to his plan of infinite wisdom, and almighty power.

### III. *The Adaptation, Uses, and Diseases of the Cellular Substance of the Muscles and Joints of the Body.*

The active parts of the system are the muscles and nerves —the muscles, to move the body and perform its offices, each submitting to its own peculiar stimuli, and most of them obeying the will,—the nerves, to feel, suffer, enjoy and issue the commands of the will, and to move the muscles to action. The muscles possess their own peculiar kind of vitality independent of the nerves. But there is a substance called the cellular substance, which not only binds and separates the muscular fibres and muscles individually and collectively, but forms coverings for the brain and nerves—sheaths for the muscles, tendons, ligaments, bursæ, and all the apparatus of the joints, and unites them into a whole, by the extensions, divisions, and duplications of its own proper substances. Tendons, or the extremities of muscles—ligaments, or the sinews—periosteum, or the membrane that covers the bones—and the bursæ, or the mucous bags that fill up and lubricate the cavities of joints,—are composed of this cellular substance, which not only combines and connects the parts by its elasticity, but is also a medium of communication for the rest of the system. The cellular substance keeps the muscles and their fibres separated at proper distances from each other, and lubricates and supports them. Its thinner halitus makes them play easy and free ; and its fat (for the cellular substance contains the fat of the body,) not only supports them in their action, but preserves their softness, and lubricates them so perfectly, that its deficiency is painful, and its superabundance cumbersome to the individual. When muscles rub on each other, the halitus (or dewy softness) of the cellular substance prevents friction and pain ; when tendon rubs on tendon—bone on bone—or muscle on tendon—the cellular substance assumes another form, and its little cells running together into one large cell, with a thicker and more copious exudation, and being literally bedewed with a gelatinous mucus—prevents the bad effects of friction. These large cells are called bursæ mucosæ, and are placed under rubbing tendons, and in large joints, to prevent friction, as circumstances require them. Every muscle is enclosed in its own cellular sheath, not only to give it pliancy, strength and form, but to preserve it in its proper position.

Tendons are not only necessary as pulleys to the bones, but to give the limbs a proper form, and preserve their beautiful symmetry. Tendons are seldom required, except where muscles are inserted into bones. There is no tendon in the heart, the stomach, the bowels, the œsophagus, and bladder ; these do not require them ; for their motions are wholly contractile, and need no lever power. But where tendons pass over bones and traverse joints, their force is concentrated into narrower bounds, and their long cords being fixed to the extremities of the muscles, pull the bones and raise them in obedience to our will. Tendons have no visible nerves, and have little feeling and no motion. The expansion of the palmaris, and many other tendons, may be unravelled into simple cellular substances. The periosteum, or membrane which surrounds the bones, is also a condensation of cellular substance, in successive layers, attached to the bones.

Tendons are implanted into the periosteum, mix with it, and become part of its substance. The tendons of muscles sometimes separate and form sheaths or rings for others. Sometimes they run in grooves formed in the bone ; at other times they expand over the bones, so as to form an entire sheath for the fingers and toes ; and are so firmly bound down, that they cannot start from the joints to which they are attached.

The periosteum of the bones is a continued membrane,—each bone is tied to the next by its own periosteum, and betwixt the end of one bone and the beginning of the next, the periosteum is thickened into a strong hard bag, forming a capsule for the joint. The capsule contains a glairy liquor that bedews the heads of the moving bones and prevents friction. There are also strong ligaments or bands, arising from the periosteum, that surround the joints and unite them firmly on every side.

When we cut or injure a tendon, or any part of a joint, the pain at first is very slight ; but soon after, when inflammation succeeds, the pain becomes excruciating. Its first action is slow ; but when roused, it is obstinate, persevering, and painful. Injury and dislocation of joints are the most acutely agonizing diseases, during inflammatory action, to which the body is subjected. The diseases of joints are almost infinite in variety. Joints are particularly subject to dropsy, gelatinous concretions, inflammation, suppuration, erosion of the cartilages, and exfoliation of the bones. Acute rheumatism is an inflammatory action around the joints, attended with a slight effusion, which is soon absorbed. Chronic rheumatism is a painful and slow inflammation, with gelatinous effusion around the tendons, permanent swelling, and lameness of the affected joint. Gout in a joint is acute inflammation, attended with secretion of earthy matter into its cavity. Inflammation of the tendons is an attendant on sprains. Effusion of gelatinous matter around the tendons forms a ganglion. Suppuration of the tendinous sheath is a whitlow

Inflammation of the bursæ, (or mucous bags,) is a *false* whiteswelling, or dropsy of the joint, which, though discharged by repeated punctures, yet in a few hours renews, and requires again to be punctured and discharged. When this species of dropsy in the mucous capsule of a joint happens in a scrofulous individual, it constitutes a *true* whiteswelling. This disease begins with inflammation of the joint, attended by pain, stiffness, and loss of power. These are followed by profuse suppuration, destruction of the cartilages, and spontaneous opening of the joint. Sometimes the disease spontaneously stops, by an effusion of calcareous matter, callus, and concretion of the bones, forming a stiff joint; but more frequently it produces hectic fever and nocturnal sweats, with extreme debility; and the emaciated patient, exhausted with fever, agony, and suffering, and reduced to a skeleton by morbid discharges and colliquative diarrhœa, dies without a struggle.

In our next we shall proceed to describe the muscles of the head and neck.

# GEOLOGY.

## CHAPTER III.

DESCRIPTION OF THE ELEMENTARY SUBSTANCES WHICH ENTER INTO THE COMPOSITION OF THE EARTH, AND THEIR MORE IMMEDIATE COMPOUNDS.

Material bodies are either simple or compound; that is, they are composed of one ingredient, or more, which no process of analyzation has hitherto been able to decompose. Few of the elementary exist as such, in the natural state. Mineral bodies, whether earthy, alkaline, or metallic, generally exist in combination with oxygen, or some other substance or substances. It is the province of chemistry to separate and recompound natural substances. The mineralogist applies himself to an investigation of their mechanical properties, as, to form, colour, hardness, opacity, transmission of light, &c. The geologist, on the other hand, considers their nature, in order to determine their origin; he discourses also of their modes of occurrence and distribution.

In giving an account of these, we shall save the reader as much as possible, from all dry unnecessary detail. It is not essential to the study of geology, that the student should be a profound chemist, or mineralogist; but without knowing the general properties and constituents of mineral bodies, he will make little progress in the science: when a small cabinet therefore can be obtained, or where students have the use of a museum, we recommend attention to the form and nature of the principal minerals and rocks, as being, with the aid of books, the best means of enabling him to converse with nature as a geologist, and with the philosopher,

> "Exempt from public haunts,
> Find tongues in trees, books in the running brooks,
> Sermons in stones, and good in everything."

*List of elementary substances found in Nature.*

1. Elements existing under ordinary pressure and temperature as gases: oxygen, hydrogen, chlorine, fluorine, nitrogen, or azote.
2. Non-metallic liquids and elements; viz., sulphur, phosphorus, selenium, iodine, bromine, boron, carbon.
3. Metalloid bodies which unite with oxygen, to form the earths and alkalies; viz., sodium, potassium, lithium, aluminum, silicum, yttrium, glucinum, thorinum, calcium, magnesium, titanium, strontium, barium.
4. Metals: manganese, zinc, iron, tin, and cadmium, which decompose water at a red heat; and arsenic, antimony, copper, molybdenum, uranium, tellurium, chromium, cerium, nickel, vanadium, cobalt, lead, tungsten, mercury, columbium, bismuth, osmium, silver, palladium, rhodium, platinum, gold, iridium, which do not decompose water.—*Phillips.*

I. *Gaseous Substances.*

*Oxygen*—so called from its property of forming acids—is one of the most important, and most widely diffused substances in nature. It enters into combination with metallic, and non-metallic bodies, so largely, that it has been computed, that one half of the ponderable matter of the globe is composed of it. Oxygen constitutes about $\frac{1}{20}$th per cent. of the volume of the atmosphere; it forms a third part; by measure of the gases composing pure water, and is locked up to an immense amount in the various rocks, which in fact are little else than a mass of oxidized substances. Plants give out oxygen, and animals absorb it. It has neither taste nor smell, and is a little heavier than the atmospheric air. The following table shows the per centage of oxygen in the earth's minerals and metals, which enter most abundantly into the composition of the crust of the earth:—

Silica = 48·4 silicum + 51·6 oxygen.
Alumina = 53·2 aluminum + 46·8 oxygen.
Magnesia = 61·4 magnesium + 38·6 oxygen.
Lime = 72 calcium + 28 oxygen.
Quartz = 48·4 metallic base + 46 oxygen.
Felspar = 54 metallic base + 44 oxygen.
Mica = 56 metallic base + 46 oxygen.
Granite = 52 metallic base + 48 oxygen.
Basalt = 57 metallic base + 43 oxygen.
Gneiss = 53 metallic base + 47 oxygen.
Clay slate = 54 metallic base + 46 oxygen.
Sandstone = from 49 to 53 metallic base + 47 to 51 oxygen.
Limestone = 52 metallic base + 48 oxygen.*

*Hydrogen* is the lightest of all known substances, being about thirteen times lighter than the atmosphere. It is combustible, and burns when pure with a yellowish white flame; it is one of the ingredients of water, of which it forms two volumes, and oxygen one. As far as the superficies of our planet is concerned, hydrogen might be supposed to constitute a substance of more relative importance than it really does, in the constitution of the globe. Its occurrence, however, in such large quantities in water, and water in a consolidated state forming no mean ingredient in the general mass of rocky matter, entitles hydrogen to be considered as next in importance to oxygen. It exists in considerable quantities in coal, and is evolved in a compound state from volcanoes and fissures (1) in coal strata.

*Chlorine,* frequently obtained from the decomposition of muriatic acid, or the spirit of salt, is largely dispersed throughout nature, but always in a state of combination, in sea-water, rock-salt; or that which is procured from brine springs, in which it is united with the metal sodium.

*Fluorine* enters into the composition of some minerals which form constituent portions of great masses of rocks. Fluoric acid is found in mica and hornblende, two minerals of very great importance, as the component parts of many rocks. From fifteen different analyzations, it has been found that

| | | | |
|---|---|---|---|
| Mica gives, . . . . . | 1·09 per cent. of | Fluoric acid. | |
| Hornblende, . . . . . | 1·05 | do. | do. |
| Gneiss with Mica, . . | 0·36 | do. | do. |
| Mica slate, . . . . | 0·54 | do. | do. |
| Hornblende rock and Greenstone, | 0·75 | do. | do. |
| Granite with Mica, . . | 0·18 | do. | do. |
| Sienite, . . . . . | 0·65 | do. | do. |
| Fluor-spar, . . . . . | 32·25 | do. | do. |

*Nitrogen* constitutes about 80 per cent. of common air. Dr Thomson found it to constitute 15·96 per cent. of the Newcastle caking coal, and it probably exists in rocks which contain the remains of animals. Nitrogen is found abundantly in the waters of some mineral springs. The king's bath, at Bath, evolves 96·5 per cent. of nitrogen, 3·5 of oxygen, and some carbonic acid. The hot well at Bristol evolves 92 per cent. of nitrogen, and 8 of oxygen. The springs at Buxton, Bakewell, and Stony Middletown, Derbyshire, evolve nitrogen only. The specific gravity of nitrogen is, 0·9722.

From the statements given, it is evident that no inconsiderable portion of the mass of the earth consists of substances, which when disengaged and set free, exist at ordinary temperatures in

* See De La Beche on the chemical composition of rocks in his Geological Manual.

the gaseous condition; under present physical conditions, oxygen, being liberated from combination with the metallic bases of the various compounds, would expand into 2000 times the bulk it possesses in solid bodies; and as it forms itself onc half of the ponderable mass near the surface of the earth, half its crust would become an atmosphere round its diminished nucleus (2). "It is evident," says Phillips, "that the tendency of this inquiry is to lend some confirmation to the speculations of Herschel and Laplace, as to the condensation of planetary bodies from gaseous expansions, like the nebulæ (3) and comets, speculations which appear to be gradually changing into probable inferences by the progress of modern astronomy."

As some of our readers may not be aware of the speculations nere alluded to, we will state briefly what they are.

The astronomical discoveries of Herschel and Laplace tend to show, that there are thousands of diffused masses of nebulous matter scattered throughout the regions of space, which assume different forms and states of consolidation, from that of thin vapour to solid masses like our own world. These are supposed to be worlds, or systems of worlds, in the act of formation; and it is inferred, that the whole matter, not only of our earth, but of the whole solar system, originally existed as a gaseous expansion also. The sun is supposed to be a solid body, surrounded with a luminous atmosphere. The central mass is considered as the nucleus or centre of an extensive expansion of gaseous matter, which had a rotatory motion: on this mass becoming more and more consolidated, the rotation increased in velocity, and the planets in consequence were thrown off successively. Herschel, the most distant, being the first, and followed by Saturn, Jupiter, the four asteroids, (4) Ceres, Pallas, Vesta, Juno, Mars, the Earth, Venus, and Mercury,—the satellites, or moons, being the most recent of the whole.

"In explaining their formation," says Dr Mantell, "it is inferred, that in any given state of the rotatory solar mass, the outer portion or ring might have its centrifugal (5) force exactly balanced by gravity; (6) but increased rotation would throw off that ring which might sometimes retain its figure, of which we have a beautiful example in Saturn. This result, however, would not take place unless the ring were of uniform composition, which would rarely be the case; hence it would most generally divide into several portions; these might sometimes be of nearly equal bulk, as in the asteroids, while in others they would coalesce into one mass. The solar nebulæ, then, thrown off at various periods, and constituting planets in a gaseous state, would each necessarily have a rotatory motion, and revolve in varying orbits round the central nucleus (the sun), and as refrigeration (cooling down,) and consolidation proceeded, each might throw off entire annuli, or rings, or satellites, in like manner as the planets themselves had been projected from the sun."

### II. *Non-metallic liquids and solids.*

*Sulphur* occurs abundantly in Sicily, and other volcanic regions; in the natural state it is found associated with the sulphate (7) of lime, strontia, carbonate of lime, and with many of the metals. Iron pyrites, which is a sulphuret of iron, is one of the most common of minerals. The sulphate of soda is always present in seawater: in the native state it is of a yellow colour, and occurs massive and crystallized—it is so well known as not to require further description.

*Phosphorus* is never found pure in nature, and is only obtained from organic matter by elaborate chemieal processes. It is yellow, and semitransparent, resembling wax in softness, but more cohesive (8) and ductile (9). Its affinity for oxygen is such, that it burns when exposed to the atmosphere.

*Selenium* was first discovered by Berzelius, among the sulphur or pyrites of Fahlun, in Sweden: it is of a gray colour with a bright metallic lustre: it is of small importance in a geological point of view: it has been classed with the metals, but rather from analogy than experiment.

*Iodine* is a bluish-black or violet coloured solid, with a metallic lustre: it is contained in seawater, and in some seaweeds and sponges.

*Bromine*, like iodine, is a marine production, it is usually obtained from the refuse of liquor in making seasalt.

*Boron* is an olive-brown powder, destitute of taste and smell, which enters into union with some of the metals and other elementary bodies. In combination with soda, it forms borax, and with oxygen, boracic acid.

*Carbon* enters largely into the composition of almost all animal and vegetable substances, and forms the basis of the combustible minerals, such as bitumen, coal, plumbago, and amber; it exists in its purest state in the diamond.

### III.—*Metalloid* (10) *bodies, which combine with oxygen, and form the earth and alkalies.*

*Sodium* is the metallic base of soda; it has the appearance of silver or of lead, and is malleable. Soda is found native in some situations, but generally obtained from the combustion of marine plants. Common salt is a chloride of sodium, consisting of 52·26 parts of soda, and 45·74 of hydrochloric acid.

*Potassium*, the metallic base of potash, which is obtained from the wood of land plants. Potash occurs in many mineral substances. There are few, if any, of the inferior stratified rocks which do not contain it. Potash is computed as constituting about 5 or 6 per cent. of the whole. Granites, greenstones, and other igneous rocks (11) of that class, contain from 6 to 7 per cent. of potash.

*Lithium*, the basis of lithia, an alkaline (12) substance, discovered by a Swedish chemist, in 1818, in the mineral Petalite. It occurs also in the mineral triphane, or spodumene. The properties of lithium are unknown, in consequence of the difficulty in procuring any quantity of its oxide.

*Aluminum*, the basis of the mineral alumina, or pure argillaceous earth, which constitutes the basis of the various clays, and is one of the most abundant and important constituent part of rocks. However abundant in a mixed state, *pure* alumina is one of the rarest substances in nature. It is soft, smooth, and unctuous (13) to the touch. Combined with other earths or rocks, it communicates to them some of their properties. Rocks, in which alumina or clay prevail, are termed argillaceous, from argilla, a Latin word, signifying clay. Some of the hardest gems, such as the ruby and sapphire, consist principally of crystallized alumina. Next to silicum, aluminum is the most important base of the earths on the surface of the globe.

*Silicum*, or silicon, the base of silica, or silex. Of the metallic bases of the earths and alkalies, silicon is the most abundant, according to De la Beche. Gneiss contains 71 per cent. of silica. Mica slate, 73 per cent. Talc slate, 78 per cent. Granite, 74. Slate, 59; &c. In pure quartz rock, silica is the only ingredient. The following minerals are chiefly composed of silica:—Quartz, or rock crystal—amethyst, prase, or green quartz —common flint—chalcedony—carnelion—bloodstone—jasper—opal, &c.

*Yttrium*, the basis of the earth yttria, the name given to a new earth, discovered by Gadolin, in 1797, in the quarry of Ytterby, in Sweden. In yttria, yttrium is found combined with the oxides of iron and manganese, and a small portion of lime and silica. When separated from these substances, it has the appearance of a fine white powder, without either taste or smell. It is infusible (14) and insoluble (15) in water.

*Glucinum*, the base of the earth glucina, which has not yet been obtained in a separate state. Glucina is obtained from the beryl, the emerald, and the euclase, of all of which it forms a constituent part.

*Thorinum.*—We obtain this earth from some varieties of the mineral gadolinite, and certain ores of cerium. Geologically speaking, it is of small importance.

*Calcium*, the basis of lime. Lime consists of 19 parts of the metallic base, calcium, and 7·5 of oxygen. The combinations of lime are most abundant in the mineral structure of the globe, and of these, as a carbonate, more or less intermixed with other substances, are the different varieties of marble, chalk, and limestone. Carbonate of lime occurs massive and crystallized. Crystallized lime is called calcareous (16) spar, which, in its mode of crystallization, has several hundred varieties, some of which are extremely beautiful. Its most usual form of crystal is that of a rhomb. It is known from white quartz by its being easily scratched by a knife, and by its readily effervescing when touched by sulphuric or nitrous acid. It abounds in almost all rocks, particularly in veins traversing limestone or trap (17) rocks, or in metallic veins. Fluor spar is a fluate of lime, and crystallizes in cubes. It is of great beauty, and often richly variegated in the massive varieties. The varieties of limestone are the different marbles, dolomite, or magnesian limestone, oolite, or roe-stone, and chalk, and a great many kinds of shell

and coralline compounds, belonging to the different stratified formations. Lime is comparatively small in quantity in the older rocks, such as granite, gneiss, and mica slate. It occurs most abundantly in rocks where organic remains abound, which has tempted some geologists to consider that all limestones have originated in organized substances. "If we examine," says MacCulloch, "the quantity of limestone in the primary strata, it will be found to bear a smaller proportion in the siliceous and argillaceous rocks than in the secondary, and this may have some connexion with the rarity of testaceous (18) animals (shellfishes) in the ancient deep." He further infers, "that in consequence of the operation of animals, the quantity of lime deposited in the form of mud or stone is always increasing, as the later far exceed the earlier strata in this respect, so a third series of rocks may hereafter arise from the depths of the ocean, which may exceed the last in the proportion of its calcareous strata. To these remarks Mr Lyell observes, "if these propositions went no farther, than to suggest that every particle of lime, that now enters into the crust of the earth, may possibly in its turn have been subservient to the purposes of life, by entering into the composition of organized bodies, I should not deem the speculation improbable; but when it is hinted that lime may be an animal product combined by the power of vitality from some simple elements, I can discover no sufficient grounds for such a hypothesis and many facts which militate against it."

*Magnesium*, the metallic basis of magnesia, has not yet been obtained; but magnesia is concluded from indirect experiments to consist of 11 of the metal, and 7·5 of oxygen. Native magnesia has only been found at one place. In New Jersey, carbonate of magnesia occurs native; in Piedmont and Moravia, we have also found it; but, only as a boulder (19), in Dumbartonshire. The following minerals contain magnesia, viz., jade, steatite or soapstone, mica talc; bitter spar, dolomite, magnesian limestone, and serpentine. In exists in a very small quantity in the waters of the ocean.

*Titanium* is only found in the titanite and in menachanite, and in the hearths of blast furnaces. In the latter it occurs native in cubes of a beautiful brown colour.

*Strontium*—the basis of strontian, a mineral originally discovered in the lead mines of Strontian in Argyleshire, but found afterwards in England, France and America. It is sometimes transparent and colourless, but has generally a tinge of green or yellow. It converts vegetable blue to green—its principal use is to communicate a beautiful red colour to flame in pyrotechnic displays.

*Barium.*—This metallic base is obtained from barytes or heavy spar, which occurs in veins in trap and other rocks. Barytes is found as a sulphate and as a carbonate only. A vein of it exists in the parish of Kilbarchan, Renfrewshire, 16 feet wide. It occurs in both stratified and igneous rocks.

(1) *Fissures*, openings or rents. (2) *Nucleus*, kernel or central mass. (3) *Nebulæ*, from *nebula*, a cloud, applied to those gaseous or hazy expansions observed revolving in space. (4) *Asteroids*, small stars. (5) *Centrifugal force*, emanating from a centre. (6) The attraction of the earth. (7) *Sulphurets* and *sulphates*, *carbonates* and *carburets*, &c., express certain definite combinations of sulphur, carbon, &c., with the metal in which these substances occur. (8) *Cohesion*, the property of adhering. Bodies are more or less cohesive in proportion to the attractive affinities of their atoms. (9) The property of being drawn out into wire, &c. (10) *Metalloid*, partaking of the nature of a metal. (11) *Igneous rocks*, those which are considered as having been produced by volcanic action. (12) *Alkaline*, belonging to the *alkalies*, being soda, potash, ammonia, &c. (13) *Unctuous*, having a greasy feel. (14) Incapable of being melted by heat. (15) Incapable of being dissolved in water. (16) From *calx*, lime. (17) *Trap*, whinstone. (18) From *testa*, a shell or covering. (19) *Boulder*, a rolled stone.

# HISTORY.

## CHAPTER II.

### ON THE LAWS OF EVIDENCE.

The various sources of historical information enumerated in the last chapter, are neither more nor less than so many collections of evidence going to establish historical facts. We have now to point out what are sometimes called the laws of evidence; that is, the rules by which we estimate the comparative credibility of different kinds of evidence, along with the reasons upon which these rules have been framed. It will then remain to indicate the manner in which these general rules can be brought to bear by the student of history, upon the sources from which he has to extract the knowledge he is in search of.

Evidence is the assertion of a fact by another, which we do not know of our own knowledge, which we have not ascertained from our experience, which has not been revealed to us by our own senses, external or internal.

A very short process of reflection will suffice to show, that for the greater portion of our knowledge we are indebted in some degree to the evidence of others. If we analyze carefully any fact we know which is resolvable into parts, we will find that it is not wholly ascertained by our own observation, but that part is believed upon the report of others. It is easy to indicate this important fact in general terms, but to have a full conception of the extent to which it is true, requires considerable reflection upon the operation of our minds, attention to the phenomena of thought of which we are conscious in the act of thinking, in addition to the subject engaging our thinking powers. The more we apply ourselves to such reflection, the more shall we feel that knowledge or opinions, adopted upon the evidence of others, are intermingled with all our thoughts in ramifications so numerous, so complicated, so minute, as to defy the power of the most subtle and patient intellect, thoroughly to distinguish and separate them. To take an example. A person sitting in a room is aware by the impression made upon his own senses, of its particular appearance, that it is of a certain shape, is bounded by four walls, a ceiling and a floor, and containing perhaps certain articles of furniture, and a number of persons. He might retire for a time into another place, and on returning, find the room he had left, and its contents, by the impression made on his own senses, exactly in the same condition. But that the room and its contents had continued during the interval of his absence, he could not know through the immediate impressions made on his own senses. There are only two ways through which he would arrive at a belief of the fact. He might, through some innate law of his thinking nature, draw the inference, because the room and its occupants presented the same appearance at his return as when he left, that it was likely that they had continued to exist in exactly the same circumstances during his absence. Or he might be told that such was the case by some person who had remained in the room during the interval. In either of these two cases—or the two may be taken together, and found corroborative of each other—the person's belief that the room existed in the same condition during his absence rests upon evidence.

We might easily proceed to a more minute analysis of the process of thinking, and point out how inextricably the knowledge we derive from evidence is blended with the knowledge we derive through sense. It is highly probable that there is not one notion or conception entertained by our thinking nature the least elevated in the scale of complexity, not even the simple processes of memory, which retain the vague and simple impressions of sound, colour, taste, or smell—of which elements derived to us through evidence do not form a part. Our purpose, however, at present is, simply to convey such a rude practical knowledge of the nature and sphere of evidence, as is necessary to awaken a due estimate of its importance.

In the preceding remarks two kinds of evidence have been enumerated. In the classes of evidence of which these two kinds are types, all other kinds of evidence may be included. These are the only means of leading us to believe in the existence of anything, when that existence is not revealed to us through the medium either of our internal or external sense. The first is the intentional assertion of a rational being that such a thing exists. The second is the observation of any one fact, the existence of which naturally and necessarily leads the mind to infer the existence of some other fact. Paley, in the opening of his Natural Theology, gives an example of the second kind of evidence, when he adverts to inference drawn by a man observing any object, from the traces of design or intention in its conception, that it must have had a maker. All our knowledge of things external to our own being, must be conveyed to us either through the medium of our senses, or by some species of evidence which may be referred to one or other of the classes we have pointed out. A person may easily convince himself of this by reflecting upon the different kinds of evidence upon which he has adopted any belief or opinion. This being the case, it may next be consid-

ered what these two classes have in common with each other. That which they have in common constitutes all that is necessarily included in the idea of evidence.

The first thing that can be predicated with certainty of any thing that constitutes evidence is, that it is a fact, having an independent existence in, and for itself, of its own. Suppose a table standing before a person, it bears evident traces of having been constructed for a purpose, and, is therefore evidence of the existence of a workman who made it. But, independent of it bearing this evidence, it is a fact that the table exists—it is a self-existing fact which the mind can comprehend, even although the mind does not employ the fact of its existence, to prove the existence of a workman who made it. The same holds true of the testimony borne by any living being to any existing fact. John, for instance, asserts, that there is ice before the door. The assertion is evidence, more or less trustworthy, that there *is* ice before the door; but, independent of this, John's assertion is a fact of itself—it is a fact, that John made the assertion, whether there is actually snow before the door or not. The first thing, therefore, that can be predicated of any kind of evidence is, that it is a fact or facts, having an independent existence. The second is, that these facts, viewed as evidence, are considered by the mind to have a use or interest, not as they exist in themselves, but in so far only as they lead the mind to the conclusion that something else exists. The existence of the table, or John's assertion, regarded as matter of evidence, are of superior consideration to the existence of the table proving the existence of a workman, or John's assertion proving the existence of ice before the door. These are the two attributes which evidence of all classes has in common, and these are all. A piece of evidence is a fact which goes to establish the existence of another fact. It is evidence only in so far as it is capable of serving this purpose, and nothing that is incapable of serving this purpose, is or can be evidence. Having ascertained what evidence is, the next important point of inquiry is the validity of evidence. Every person of ordinary thinking powers must be aware, that different pieces of evidence possess different degrees of force. Some kinds of evidence produce an amount of conviction only second to (if indeed it be second to) what is produced by the impressions of our own senses. Others again produce a faint and hesitating assent. In the preceding remarks, two great classes of evidence, naturally marked and distinguished from each other, have been pointed out. Let us examine whether there be anything in the nature of either to render its persuasive force, necessarily different in degree from that of the others.

The first class is the express testimony of a thinking being; the second is the testimony of an existing fact. John, for instance, pointing to a table, asserts that it was made by an intelligent being; the table is there, and is of itself a proof that it was made by an intelligent being; and taken together, these two pieces of evidence go to establish the fact, that the table was made by an intelligent being. Their probative force will differ according to the kind of mind to which they are addressed. The man of experience and reflection will see stronger evidence in the existence of the table itself than in the assertion of any man, and will even use the marks of design apparent in the table as a test of John's credibility; and were John to assert that the table was not made, he would believe the evidence of the table itself in preference. On the other hand, a person of little experience, and little accustomed to reflection, might overlook the indications of design, and to him John's evidence would appear more weighty. This difference in the persuasive force of these two kinds of evidence is not inherent,—it is extraneous and accidental, and, to make our inquiries satisfactory in comparing the respective values of evidence, we must suppose these operating upon a mind of average intelligence.

To return to our example, the fact that a mind of average intelligence would be apt to test the correctness of John's statement by the indications of design in the construction of the table, settles at once the question of superior probative force in the instance we have chosen. The indications of design existing in the table are surer proof of an intelligent maker than John's evidence can possibly be. It would, however, be rash from this instance to jump at the conclusion, that the whole class of evidence to which John's testimony belongs is weaker than the whole class to which the testimony of the table's existence belongs. The evidence borne by existing facts varies very widely in degree. In selecting a table we selected a medium instance in which the indications of design are sufficiently strong. In Paley's instance of a watch, these are much stronger. On the other hand, we have examples of blocks of stone, and logs of wood, fashioned by the uninstructed savage, so rudely executed that, were we to stumble upon them by accident, we should be at a loss to determine whether the marks upon them were the work of man or the effects of accident. The consideration of these facts furnishes us with the materials for an ascending and descending scale of the varying forces of the different kinds of inanimate or unintentional evidence.

Turning next to the consideration of intentional evidence, we find its most marked difference from an unintentional or necessary evidence consists in this, that it has none of those unerring characteristics which render its precise value unquestionable, and that on the other hand, it has a much wider range. The unintentional evidence of the table can go no further than to establish the fact, that a maker exists or existed. The intentional evidence of John, however, can go farther; it can point out the individual who was the maker. Intentional evidence has therefore an advantage over unintentional, in as much as it may be more comprehensive and explicit; but then, it is much more difficult to ascertain its trustworthiness. A man may wish to tell the truth, or he may want to deceive us; or he may intend to tell us the truth, and yet be incapable, from not comprehending or knowing the truth himself. In this manner we may form a descending scale of the value of intentional evidence. At the top stands the evidence of him who knows and tells the truth; and at the bottom the evidence of him who possesses neither the ability to ascertain, nor the desire to tell the truth. The intermediate grades are filled up by the evidence of such as are more or less deficient in one or both of these requisites.

But how are we to ascertain the character, or value, of an intentional piece of evidence? This question brings us to another kind of evidence—corroborative evidence. This kind differs not in its nature from direct evidence. It may be the direct evidence of a fact to which the mind only attaches importance, in so far as it goes to establish another fact. It falls under the two great classes of intentional and unintentional evidence; and may be arranged according to its varying degrees of persuasive force. The difference between direct and corroborative evidence is simply this:—that direct evidence goes to establish the existence of a fact men seek to know on its own account; and corroborative evidence goes to prove the character of the direct evidence, because the establishment of its trustworthiness will prove the existence of another fact. The intentional evidence of an individual always stands in need of corroborative evidence. We want proofs to prove that his evidence is trustworthy. These facts are of various kinds, and of different degrees of value. The fact that the individual bearing testimony is capable of apprehending truth, is a corroborative evidence. So is the fact that he underlies no motive to tell an untruth; or still more, that he has a motive to tell truth. Any two of these combined are still more strongly corroborative of the truth of the evidence. Again; unintentional evidence may be corroborative of intentional evidence, and *vice versa.* The story of the person giving intentional evidence may involve a statement of physical facts; and if these facts correspond with the testimony given, the confirmation is a corroborative evidence that the rest of his evidence is true. Or, in the absence of any of these elements of corroborative evidence, if the story is long, corroborative evidence may be obtained by a critical analysis of the parts, to see how they cohere, and if the motives attributed, and the time, place, and other circumstances mentioned, confirm each other. Or, corroborative evidence may be obtained by examining the difference or sameness of evidence given by the same person, of the same facts, at different times. Evidence, corroborative of unintentional evidence, may be afforded by direct intentional testimony to the design, which, without such testimony, we should have been inclined to infer from the appearance of what constitutes the unintentional evidence.

Circumstantial evidence is a term used to denote a collection of facts, no one of which could of itself be taken as evidence of another fact; but the simultaneous existence of which can only be accounted for by the assumption of that other fact. For example. A body is found with a deadly wound in it; an individual is found sleeping at a considerable distance, with blood upon his clothes; when awakened, he is confused and alarmed, and gives

an incoherent account of himself; it is discovered that there had been a quarrel between the two: lastly, it is proved that the sleeper had been seen not long before the discovery of the body, near the spot where it was found. Any one of these circumstances would, of itself, be unable to awaken a suspicion—not one of them could be viewed as constituting even the least and lowest grade of evidence against the sleeper. But taken altogether, they point irresistibly to the conclusion, that had he not been the murderer, so many concurring circumstances would not have been noted against him.

This sketch, though rough and imperfect, may serve to convey a general view of the different kinds of evidence, their respective bearings upon each other, and enable us to establish certain general canons to guide us in the examination and appreciation of the evidence to be submitted in the present field of inquiry.

The first canon is quite general, and alike applicable to all evidentiary facts—to make ourselves masters of the evidentiary facts immediately submitted to our cognizance, in all its bearings and details, with the utmost possible accuracy. A hasty and superficial examination leads to imperfect apprehension; and imperfect apprehension leads to erroneous inferences. Again; while learning the evidentiary fact, we must carefully banish from our mind, for the time, its evidentiary character. We must look at it for itself alone; for if we keep in mind that it is only as evidence to a further fact that it will suit our purpose, we incur great danger of allowing ourselves to apprehend it in such a manner as will render it fit for our purposes. We cannot be too careful in guarding against this; for we can never be quite certain that some latent wish has not modified our opinions, any more than we can be certain that long entertained opinions have not given a bias to our wishes. We must be careful to see things as they actually are, not as we would wish them to be. It is against this natural tendency that we must always be on the alert to struggle when examining questions of evidence.

The second canon is, that there are two great classes of evidence, under one or other of which, all special kinds of evidence may be arranged. First, facts that, by their mere existence, lead the mind, by a necessary law, to conclude that certain other facts exist—this class may be termed unintentional, or necessary evidence. The second class consists of statements made by rational intelligent beings—this may be termed intentional evidence. The former is the surer, as far as it goes; while the latter is more extensive in its range, and minute in detail.

The third canon is, that all evidence—alike intentional and unintentional—may be divided into two other great classes, according as it is direct or corroborative. Direct evidence is that which goes simply and at once to establish the existence of a fact inquired after. Corroborative evidence is that which goes to strengthen evidence in itself direct, but not altogether conclusive. Corroborative evidence is of two kinds. The first consists of evidence which simply goes to establish the existence of the evidentiary fact. The second may more properly be called supplementary evidence. When, for instance, we seek to prove a fact by two pieces of evidence, the one may be intentional and the other unintentional; either of which is too weak to establish the existence of the fact we are seeking; if, on comparing the one with the other, they mutually agree, the one will be supplementary to the other, and between them the existence of the fact may be evidenced with greater force, than by an evidentiary fact standing higher in the scale of evidence, but standing alone.

The fourth canon is, that there remains an inferior kind of evidence with which we must sometimes put up in the absence of all other kinds, which only goes to establish a presumption, more or less strong, that the evidentiary fact must exist. This form of evidence is called circumstantial evidence, and ranks the lowest and weakest of all. It consists of a number of facts, or circumstances, pointing to one conclusion, and which, when arranged together, lead to the supposition of the existence of some fact.

To construct a scale of the various kinds of evidence, ranged according to their persuasive force, in detail, would far exceed our limits. The following, in which we begin at the top and descend, indicates the most remarkable degrees, and may be filled by a more minute analysis than we can at present enter upon:—

1st. Intentional testimony duly corroborated.
2d. Unintentional testimony duly corroborated.
3d. Unintentional testimony partially, or not corroborated.
4th. Intentional testimony partially, or not corroborated.
5th. Circumstantial evidence.

It now remains to point out the direct application of these canons of evidentiary criticism, to the sources enumerated, and partially illustrated, in the last chapter.

The sources of historical information were divided into two great classes—written records and monumental remains. These correspond exactly to the two great divisions of evidentiary facts —intentional and unintentional evidence.

Written records are intentional evidence of a peculiar kind. They are what is called written, in opposition to oral testimony, both of which, however, are expressions of intentional evidence. Written communication labours under this defect as compared with oral, that, in almost every instance, it is necessary to prove that the written testimony is really the written testimony of the individual from whom it purports to emanate. In old written records this is not easy to do. When, however, the author of a written record is clearly established, it always possesses one advantage over oral—it is more precise, more susceptible of repeated examination and scrutiny. But there is a variation in the persuasive force of written evidence peculiar to itself. The evidence once written down remains unsusceptible of change; but it may have been liable to more or less modification in the mind of the writer before it was committed to writing. Assuming that the character of the writer is beyond suspicion, and that the authorship of the writing is clearly established, there still remains the question, did he commit his narrative to writing at the time when the facts narrated occurred, or only at a later period? In the first case, the impression on his mind is fresh and likely to be accurate. In the second, the impression has become faint and dulled by length of time; and imagination or passion may even unconsciously have played strange freaks in altering and distorting the narrative. These considerations suggest an enumeration of the different written sources of historical evidence, beginning at the most trustworthy and descending.

First on the list, stand public records of the transactions of legislative or judicial bodies; the business of which was transacted in public. These are compiled at the moment, and under the eye of the public; and it being the interest of the compilers to be accurate, they are the more to be depended on.

Second on the list, stand narratives of events by contemporaries, whose natural sagacity, acquired knowledge, and sincerity, are proved by external evidence; the texture of which is consistent with itself, and in keeping with the monumental remains of the period to which they relate. According as one or other of these qualifications is wanting, the work descends in the scale of evidence.

Third on the list, stand narratives compiled by men of a later time, when the authors are men of natural sagacity and probity, experienced in public and domestic business, and extensively acquainted with the records of antiquity, and with ample access to investigate the written and monumental remains of the period they write about. This class is, like the preceding, susceptible of corroborative evidence from its own internal consistency, or its correspondence to the monumental remains of the period, the history of which it records.

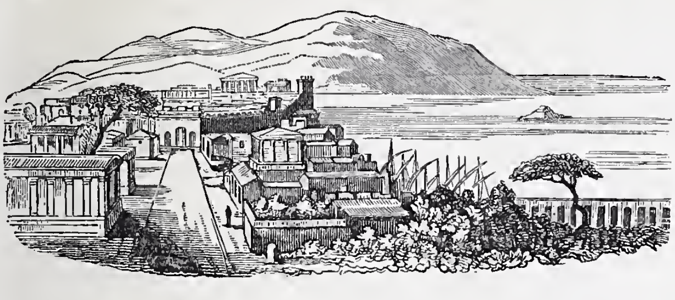
At the bottom of the scale stand works of two classes:—anonymous works, the age of which can be proved, although the author is altogether unknown; and works attributed to some well-known and credible writer, indirectly vouched to be his by something in their style, but wanting a clear consecutive proof of their paternity.

Monumental remains are unintentional evidence; some of them, it is true, being raised to perpetuate the memory of men or events, are incorrectly designated by this phrase. These monuments, inscriptions, coins, and the like, may be regarded as blending in one the characteristics of both the great classes of evidence. But to the great class of monumental remains this does not apply. They differ in their value as evidence, according to the amount of indication of design they originally contained, or which the ravages of time have left uneffaced. They differ likewise in value, according as they are more or less corroborated by the intentional evidence of written records.

At the head of the scale, in this class, stand the cities of Pompeii and Herculaneum, overwhelmed together in the great eruption of Vesuvius, A.D. 79, and destined to be partners in disinterment as well as in burial. There was, however, this difference in their fate—that, owing to its greater distance from the volcano, the former was not then, and never has been, reached by the streams of lava which have successively flowed over Herculaneum, and elevated

the surface of the earth from 70 to 100 feet. Pompeii was buried by a shower of ashes, pumice, and stones, forming a bed of variable depth, but seldom exceeding 12 or 14 feet, loose and friable in texture, and therefore easily removed, so as completely to uncover and expose the subjacent buildings.

The upper stories of the houses, which appear to have consisted chiefly of wood, were either burnt by the red-hot stones ejected from Vesuvius, or broken down by the weight of matter collected on their roofs and floors. With this exception, we see a flourishing city in the very state in which it existed nearly eighteen centuries ago—the buildings as they were originally designed, not altered and patched to meet the exigencies of newer fashions; the paintings un-



POMPEII FROM THE GATE OF HERCULANEUM.

dimmed by the leaden touch of time; household furniture left in the confusion of use; articles, even of intrinsic value, abandoned in the hurry of escape, yet safe from the robber, or scattered about as they fell from the trembling hand, which could not pause or stoop for its most valuable possessions; and, in some instances, the bones of the inhabitants, bearing sad testimony to the suddenness and completeness of the calamity which overwhelmed them.

"I noticed," says M. Simond, "a striking memorial of this mighty eruption in the Forum, opposite to the temple of Jupiter. A new altar of white marble, exquisitely beautiful, and apparently just out of the hands of the sculptor, had been erected there; an enclosure was building all round; the mortar, just dashed against the side of the wall, was but half spread out; you saw the long sliding stroke of the trowel about to return and obliterate its own track—but it never did return: the hand of the workman was suddenly arrested, and, after the lapse of 1800 years, the whole looks so fresh and new that you would almost swear the mason was only gone to his dinner, and about to come back immediately to smooth the roughness."

Among the most curious things discovered, were seven glazed plates found packed in straw, many bronze lamps and stands,

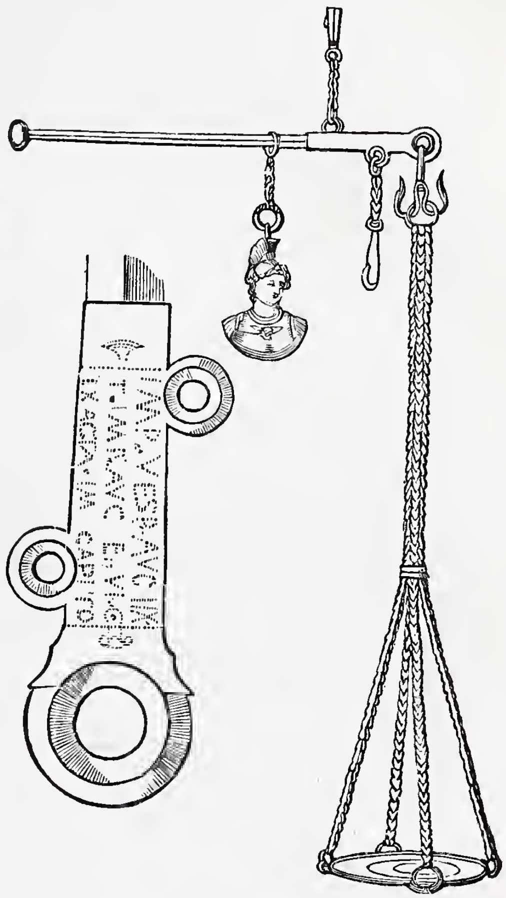
BRONZE LAMP AND STAND FOUND AT POMPEII.

unvarnished vases of terra-cotta, clay dishes, a large pestle and mortar, and the steelyard which we have here engraved. On the beam of the steelyard are Roman numerals from X. to XXXX.; a V was placed for division between each X., smaller divisions are also marked.

The inscription is

IMP. VESP. AVG. IIX.
T. IMP. AVG. F. VI. C.
EXACTA. IM. CAPITO.

which is translated thus:—"In the eighth consulate of Vespasian Emperor Augustus, and in the sixth of Titus Emperor and son of Augustus, Proved in the Capitol." This shows the great care taken to enforce a strict uniformity in the weights and measures used throughout the empire: the date corresponds with the year 77 of our era, only two years previous to the great eruption. The steelyard found was also furnished with chains and hooks, and with numbers up to XXX.



STEELYARD FOUND AT POMPEII.

The period in which the eruption occurred was one in which the march of civilization had so far developed institutions, and separated occupations, as to render their annals full and particular; and so far advanced the habits of domestic life, as to render them fit objects for the graphic hand of the poetical or prose narrator. We have details of the fatal eruption by an eye-witness, contained in two letters of Pliny the younger to Tacitus, which record the death of his uncle, who fell a victim to his inquiring spirit and humanity.

"Your request that I would send you an account of my uncle's death, in order to transmit a more exact relation of it to posterity, deserves my acknowledgments; for, if this accident shall be celebrated by your pen, the glory of it, I am well assured, will be rendered for ever illustrious. And, notwithstanding he perished by a misfortune, which, as it involved, at the same time, a most beautiful country in ruins, and destroyed so many populous cities, seems to promise him an everlasting remembrance; notwithstanding he has himself composed many and lasting works; yet, I am persuaded, the mentioning of him in your immortal works will greatly contribute to eternize his name. Happy I esteem those to be, whom Providenee has distinguished with the abilities either of doing such actions as are worthy of being related, or of relating them

in a manner worthy of being read; but doubly happy are they who are blessed with both these uncommon talents; in the number of which my uncle, as his own writings and your history will evidently prove, may justly be ranked. It is with extreme willingness, therefore, I execute your commands; and should indeed have claimed the task, if you had not enjoined it. He was at that time with the fleet under his command at Misenum. On the 24th of August, about one in the afternoon, my mother desired him to observe a cloud which appeared of a very unusual size and shape. He had just returned from taking the benefit of the sun,* and, after bathing himself in cold water, and taking a slight repast, was retired to his study. He immediately arose and went out upon an eminence, from whence he might more distinctly view this very uncommon appearance. It was not at that distance discernible from what mountain this cloud issued, but it was found afterwards to ascend from Mount Vesuvius. I cannot give a more exact description of its figure, than by resembling it to that of a pine-tree, for it shot up a great height in the form of a trunk, which extended itself at the top into a sort of branches; occasioned, I imagine, either by a sudden gust of air that impelled it, the force of which decreased as it advanced upwards, or the cloud itself being pressed back again by its own weight, expanded in this manner: it appeared sometimes bright and sometimes dark and spotted, as it was more or less impregnated with earth and cinders. This extraordinary phenomenon excited my uncle's philosophical curiosity to take a nearer view of it. He ordered a light vessel to be got ready, and gave me the liberty, if I thought proper, to attend him. I rather chose to continue my studies; for, as it happened, he had given me an employment of that kind. As he was coming out of the house, he received a note from Rectina, the wife of Bassus, who was in the utmost alarm at the imminent danger which threatened her; for her villa being situated at the foot of Mount Vesuvius, there was no way to escape but by sea: she earnestly entreated him, therefore, to come to her assistance. He accordingly changed his first design, and what he began with a philosophical, he pursued with an heroical turn of mind. He ordered the galleys to be put to sea, and went himself on board with an intention of assisting not only Rectina, but several others; for the villas stand extremely thick upon that beautiful coast. When hastening to the place from whence others fled with the utmost terror, he steered his direct course to the point of danger, and with so much calmness and presence of mind, as to be able to make and dictate his observations upon the motion and figure of that dreadful scene. He was now so nigh the mountain, that the cinders, which grew thicker and hotter the nearer he approached, fell into the ships, together with pumice-stones, and black pieces of burning rock: they were likewise in danger, not only of being aground by the sudden retreat of the sea, but also from the vast fragments which rolled down from the mountain, and obstructed all the shore. Here he stopped to consider whether he should return back again; to which the pilot advising him, 'Fortune,' said he, 'befriends the brave; carry me to Pomponianus.' Pomponianus was then at Stabiæ,† separated by a gulf, which the sea, after several insensible windings, forms upon the shore. He had already sent his baggage on board; for though he was not at that time in actual danger, yet being within the view of it, and, indeed, extremely near, if it should in the least increase, he was determined to put to sea as soon as the wind should change. It was favourable, however, for carrying my uncle to Pomponianus, whom he found in the greatest consternation: he embraced him with tenderness, encouraging and exhorting him to keep up his spirits, and the more to dissipate his fears, he ordered, with an air of unconcern, the baths to be got ready; when, after having bathed, he sat down to supper with great cheerfulness, or at least (what is equally heroic) with all the appearance of it. In the meanwhile, the eruption from Mount Vesuvius flamed out in several places with much violence, which the darkness of the night contributed to render still more visible and dreadful. But my uncle, in order to sooth the apprehensions of his friend, assured him it was only the burning of the villages, which the country people had abandoned to the flames; after this he retired to rest, and it is most certain he was so little discomposed as to fall into a dead sleep; for being pretty fat, and breathing hard, those who attended without actually heard him snore. The court which led to his apartment being now almost filled with stones and ashes, if he had continued there any time longer, it would have been impossible for him to have made his way out; it was thought proper, therefore, to awaken him. He got up, and went to Pomponianus and the rest of his company who were not unconcerned enough to think of going to bed. They consulted together whether it would be most prudent to trust to the houses, which now shook from side to side with frequent and violent concussions; or fly to the open fields, where the calcined stones and cinders, though light indeed, yet fell in large showers, and threatened destruction. In this distress they resolved for the fields, as the less dangerous situation of the two; a resolution which, while the rest of the company were hurried into by their fears, my uncle embraced upon cool and deliberate consideration. They went out then, having pillows tied upon their heads with napkins; and this was their whole defence against the storm of stones that fell around them. It was now day every where else, but there a deeper darkness prevailed than in the most obscure night; which, however, was in some degree dissipated by torches and other lights of various kinds. They thought proper to go down farther upon the shore, to observe if they might safely put out to sea; but they found the waves still run extremely high and boisterous. There my uncle, having drunk a draught or two of cold water, threw himself down upon a cloth which was spread for him, when immediately the flames, and a strong smell of sulphur, which was the forerunner of them, dispersed the rest of the company, and obliged him to rise. He raised himself up with the assistance of two of his servants, and instantly fell down dead; suffocated, as I conjecture, by some gross and noxious vapour, having always had weak lungs, and being frequently subject to a difficulty of breathing. As soon as it was light again, which was not till the third day after this melancholy accident, his body was found entire, and without any marks of violence upon it exactly, in the same posture that he fell, and looking more like a man asleep than dead. During all this time my mother and I, who were at Misenum ‡—But as this has no connexion with your history, so your inquiry went no farther than concerning my uncle's death; with that, therefore, I will put an end to my letter: suffer me only to add, that I have faithfully related to you what I was either an eye-witness of myself, or received immediately after the accident happened, and before there was time to vary the truth. Farewell!"

"The letter which, in compliance with your request, I wrote to you concerning the death of my uncle, has raised, it seems, your curiosity to know what terrors and dangers attended me while I continued at Misenum; for there, I think, the account in my former broke off.

"My uncle having left us, I pursued the studies which prevented my going with him, till it was time to bathe. After which I went to supper, and from thence to bed, where my sleep was greatly broken and disturbed. There had been, for many days before, some shocks of an earthquake, which the less surprised us as they are extremely frequent in Campania; but they were so particularly violent that night, that they not only shook everything about us, but seemed indeed to threaten total destruction. My mother flew to my chamber, where she found me rising, in order to awaken her. We went out into a small court belonging to the house, which separated the sea from the buildings. As I was at that time but eighteen years of age, I know not whether I should call my behaviour, in this dangerous juncture, courage or rashness; but I took up Livy, and amused myself with turning over that author, and even making extracts from him, as if all about me had been in full security. While we were in this posture, a friend of my uncle's who was just come from Spain to pay him a visit, joined us; and observing me sitting by my mother with a book in my hand, greatly condemned her calmness, at the same time that he reproved me for my careless security. Nevertheless, I still went on with my author. Though it was now morning, the light was exceedingly faint and languid; the buildings all around us tottered, and though we stood upon open ground, yet, as the place was narrow and confined, there was no remaining there without certain and great danger: we therefore resolved to quit the town. The people followed us in the utmost consternation, and, as to a mind distracted with terror every suggestion seems more prudent than its own, pressed in great crowds about us in our way out. Being got at a convenient distance from the houses, we stood still, in the midst of a most dangerous and dreadful scene. The chariots which we had ordered to be drawn out, were so agitated backwards and forwards, though upon the most level ground, that we could not keep them steady, even by supporting them with large stones. The sea seemed to roll back upon itself, and to be driven from its banks by the convulsive motion of the earth; it is certain, at least, the shore was considerably enlarged, and several sea animals were left upon it. On the other side a black and dreadful cloud, bursting with an igneous serpentine vapour, darted out a long train of fire, resembling flashes of lightning, but much larger. Upon this our Spanish friend, whom

* The Romans used to lie or walk naked in the sun, after anointing their bodies with oil, which was esteemed as greatly contributing to health, and therefore daily practised by them.

† Now called Castel a Mar di Stabia, in the Gulf of Naples.

‡ See this account continued in the following letter.

I mentioned above, addressing himself to my mother and me with great warmth and earnestness: 'If your brother and your uncle,' said he, 'is safe, he certainly wishes you may be so too; but if he perished, it was his desire, no doubt, that you might both survive him: why, therefore, do you delay your escape a moment?' We could never think of our own safety,' we said, 'while we were uncertain of his.' Hereupon our friend left us, and withdrew from the danger with the utmost precipitation. Soon afterwards the cloud seemed to descend, and cover the whole ocean; as indeed it entirely hid the island of Capraæ,* and the promontory of Misenum. My mother strongly conjured me to make my escape at any rate, which, as I was young, I might easily do: as for herself, she said, her age and corpulency rendered all attempts of that sort impossible. However, she would willingly meet death, if she could have the satisfaction of seeing that she was not the occasion of mine. But I absolutely refused to leave her, and, taking her by the hand, I led her on: she complied with great reluctance, and not without many reproaches to herself for retarding my flight. The ashes now began to fall upon us though in no great quantity. I turned my head, and observed behind us a thick smoke, which came rolling after us like a torrent. I proposed, while we had yet any light, to turn out of the high road, lest she should be pressed to death in the dark by the crowd that followed us. We had scarce stepped out of the path, when darkness overspread us, not like that of a cloudy night, or when there is no moon, but of a room when it is shut up, and all the lights extinct. Nothing then was to be heard but the shrieks of women, the screams of children, and the cries of men; some calling for their children, others for their parents, others for their husbands, and only distinguishing each other by their voices; one lamenting his own fate, another that of his family; some wishing to die from the very fear of dying; some lifting their hands to the gods; but the greater part imagining that the last and eternal night was come, which was to destroy the gods and the world together.† Among these were some who augmented the real terrors by imaginary ones, and the frighted multitude falsely believe that Misenum was actually made in flames. At length a glimmering light appeared, which we imagined to be rather the forerunner of an approaching burst of flames, as in truth it was, than the return of day. However, the fire fell at a distance from us; then again we were immersed in thick darkness, and a heavy shower of ashes rained upon us, which we were obliged every now and then to shake off, otherwise we should have been crushed and buried in the heap. I might boast that, during all this scene of horror, not a sigh or expression of fear escaped from me, had not my support been founded in that miserable though strong consolation—that all mankind were involved in the same calamity, and that I imagined I was perishing with the world itself! At last this dreadful darkness was dissipated by degrees, like a cloud of smoke; the real day returned, and even the sun appeared, though very faintly, and as when an eclipse is coming on. Every object that presented itself to our eyes (which were extremely weakened) seemed changed, being covered over with white ashes, as with a deep snow. We returned to Misenum, where we refreshed ourselves as well as we could, and passed an anxious night between hope and fear; though indeed with a much larger share of the latter; for the earthquake still continued, while several enthusiastic people ran up and down, heightening their own and their friends' calamities by terrible predictions. However, my mother and I, notwithstanding the danger we had passed, and that which still threatened us, had no thoughts of leaving the place till we should receive some account from my uncle."—*Pliny's Letters*, vi. 20; Melmoth's Translation.

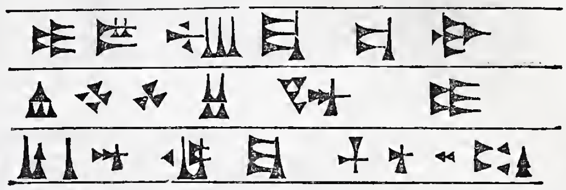
Next in order come the wonderful remains of ancient Egypt; her solid colossal temples, and pictured tombs. Of the language of the time when they were reared, we can only guess that its roots are still the main ingredient of a barbarous and imbecile dialect confined to a small portion of the present inhabitants. We are now beginning to understand the meaning of some of the characters which express it, but they suggest no sound to our ears. Of the public and private history of the nation which produced them, we possess nothing but disjointed scraps, in the language of alien tribes, and of a later day.

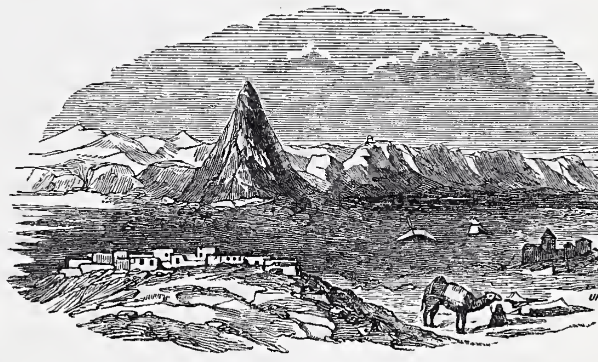
* An island twenty miles from Naples, now called Capri.

† The stoic and epicurean philosophers held that the world was to be destroyed by fire, and all things fall again into original chaos; not excepting even the national gods themselves from the destruction of this general conflagration

And yet the freshness of these huge structures, and of the quarries whence they have been dug, and the characteristic nature of the paintings, tell a more intelligible story than many written records. The hints in Greek and Jewish story suffice to furnish us with an approximation to the time when, and the people by whom, these imperishable works were executed. The remains of their temples, the traces in their quarries, enable us to estimate their vigour of conception and power of execution: the paintings on the walls of their sepulchral chambers revive for us the triumphs of their monarchs, and also the daily occupations and the amusements of the people. It is scarcely an exaggerated, though a somewhat grotesque image, to say that we behold the Egyptians through the long vista of time, as we can conceive ourselves to see the inhabitants of the moon through a telescope: we see their forms and occupations, but all is dead and visionary silence—no hum of life, however faint and distant, reaches our ears.

Descending still farther in the scale of probative forces, we come to some shapeless mounds on the banks of the Euphrates and Tigris. To the careless eye it would be impossible to say whether they were natural hillocks or heaps of mould, beneath which crumbled the remains of old abodes of men. At times a brick was dug up impressed with strange characters, which no one could decipher. But the bitumen adhering to the bricks, and the reeds interspersed with the bitumen, recalled to mind what is said in the oldest written records of our race, in the earliest recorded building of men.





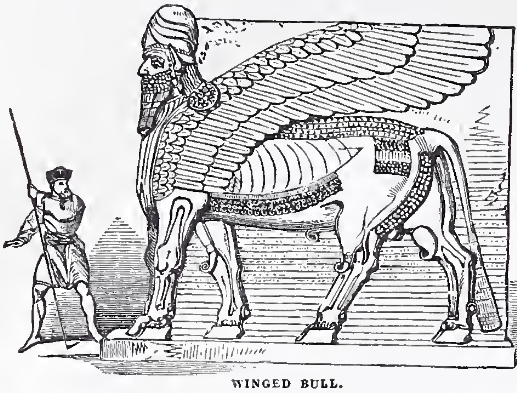
THE MOUND AT NIMROD.

The local position of one cluster of mounds corresponds with the local position assigned by old writers to Babylon. Tradition also assigned the eastern bank of the Tigris opposite to Mosul, as the site of Nineveh, the city of Nimrod, the mighty hunter.

That which but a few years since was to us mere conjecture is now an ascertained fact. Such a field for research was not destined to remain for ever neglected. Though silent and lonely, in the midst of a parched desert, and far removed from the highway of commerce or travel, the noble enterprise of an English scholar and a French savant have exhumed from its shroud of sand and ruin the dead city. For two thousand years it had been blotted from the world; its very grave unknown to the nations who had groaned beneath its sway. M. Botta, then French consul at Mosul, was the first whose attention was directed to the examination of these singular mounds of sand and rubbish. He commenced his excavations in the great mound of Kouyunjik, but finding little there, he directed his search to the mound of Khorsabad, and, in 1843, exposed to the light the first Assyrian building which man has beheld since the fall of the Assyrian empire. Layard, stimulated by the success attending Botta's researches, without the permission, or even the cognisance of the Turkish authorities, in 1845, commenced those excavations at Nimroud which were destined to render his name immortal.

We shall not here attempt to follow Layard in his dangers, in

his toil, and in his final triumphant success in disintombing the buried city of Nineveh—the twin sister of *Babylon*—the Nineveh in which the captive tribes of Israel had laboured and wept, and which, after a sleep of twenty centuries, is again brought to light. The long-lost is found—the proofs of ancient splendour are again beheld by living eyes, and, by the skill of the draughtsman, and the pen of the antiquarian traveller, made known to the world.



WINGED BULL.

These discoveries have completed the chain of history which extends from our own days to those of the immediate descendants of Noah, and furnishes a striking testimony to the veracity of the sacred writings, and the literal fulfilment of prophecy. Layard is still prosecuting his researches with vigour and success. He has (1851) also extended his researches to Babylon, and is examining the various ancient cities that are scattered over that extensive country, with a view of ascertaining the spots most favourable for excavation.

Such is a brief notice of the late wonderful discoveries in Assyria; but we intend devoting our last chapter on history to giving a detailed account of the discoveries made by Botta and Layard, illustrating by drawings some of the most remarkable remains deposited in the British Museum.

Last of all are the grey stones and lonely cairns of forgotten heroes, so rife in all lands. Rude in form, they carry us back to the infancy of society; but history and tradition are alike silent regarding them.

Thus, then, the general principles above enumerated are found of easy application in testing the value of this mass of historical evidence. The practical application of the canons we have sought to establish involves no greater difficulty. Our first task is to form notions exactly corresponding to the original of story or monument—to understand the one and know the other correctly, and in detail. The next is to ascertain the exact use that can be made of each; whether it is qualified to serve directly as an evidentiary fact, or indirectly as a means of proving the existence of an evidentiary fact. Then comes a critical examination of the tissue of each narrative, with a view to appreciate the author's character, moral and intellectual—a comparison of its statements with what is said in other writings or found in monumental remains, in order to test its accuracy—an inquiry into the history of the work in order to be sure of its authenticity. All these inquiries are indispensable, in order that we may know its value as a matter of evidence. Thus we go on ascertaining and collecting facts by the exercise of the reasoning faculty, which we are afterwards to bring together and arrange, by the aid of judgment, into a structure in which the glad imagination shall recognise the perished adventures of old times, born again to a life which can have no end—for the soul in which they henceforth live is itself immortal.

# MINERALOGY

## CHAPTER I.

The most proper definition of Mineralogy that can be given, seems to be that of Kirwan, viz., the art of distinguishing mineral substances from each other.

In mineralogy, the component parts of the earth's crust are not thought of, or treated, in the mass, or with reference to the past history, or the future condition of our globe; that department of science belongs to geology, and includes some of the loftiest subjects of human thought; but the properties of the natural combinations of mineral matter are investigated simply for the purpose of arranging in scientific order those infinitely varied combinations. In one view Mineralogy is but the handmaid of her noble sister Geology; in another it is allied to every art ministering to man's daily wants, that finds its material in the substance of the earth.

Formerly the rules by which mineral substances were arranged, were drawn from external appearances only, and mineralogy was a specimen of empiricism unworthy the name of a science. But since the principles of chemistry have been placed on a truer basis, and the processes of chemical investigation perfected, mineralogy has derived the most valuable assistance from that science. It may be said, indeed, that chemistry has entirely remodelled mineralogy; and although a system of classification founded on chemistry is attended with many difficulties, yet it is by far the best, and, in fact, the only true classification. Still it is by no means advisable to lay aside entirely a consideration of the external properties of minerals, because bodies are much more readily recognised and catalogued by their outward features than by their chemical composition.

The student who approaches any one branch of physical science, for the first time, finds upon closer inspection that it is intimately connected with other sciences, and that he cannot stir one step without calling in the aid of knowledge beyond the limits of that to which he has applied himself. Mineralogy is no exception; it is in fact a striking example of the connection of physical sciences. Without an acquaintance with the rudiments, at least of chemistry, mechanics, and mathematics, there will be little progress in mineralogy. A knowledge of chemistry is as we have already shown most essential, whilst mathematics and mechanics throw powerful light on the principles which have determined the shape and consistency of minerals. Crystallography or that branch of mineralogy which deals with crystallised bodies, deducing complicated forms from simple, and tracing through many varieties the same leading feature, cannot be understood without some acquaintance with exact science.

In addition to the general characteristics of *colour* and *form*, those of *structure*, *hardness*, *fracture*, *specific gravity*, *transparency* or *opacity*, *lustre*, *taste*, and *smell*, assist in distinguishing minerals from one another. As to *form* they are divided into two great classes, crystallised and non-crystallised. For the present we defer saying any thing on the first class, and proceed to say of the second, that it consists of amorphous bodies, or those without any particular form, and bodies with determinate forms, such as acicular or needle-shaped, arborescent or branch-like, botryoidal, having the shape of a half-dissolved bunch of grapes, capillary or hair-like, mammillated, a slight variation of the botryoidal form, nodular, that is, in spherical lumps, pulverulent, in small particles, reniform, or kidney-shaped, and stalactitic. In some cases *colour* is a very distinctive character; in others it forms but a slight distinguishing mark, in consequence of some minerals having all diversities of colour. Taste is sometimes resorted to as a means of ascertaining a mineral, especially in the case of salts; and *smell*, when perceptible, is another criterion. Thus, bodies which contain much alumina give out a peculiar odour when breathed on, and the metals arsenic and iron are easily detected by the tongue. Some mineralogists have formed a scale of the *hardness* of minerals consisting of ten degrees, thus: 1. Talc, white or greenish. 2. Rock-

salt, and uncrystallised gypsum. 3. Calcareous spar, cleavable. 4. Fluor-spar, perfectly cleavable. 5. Apatite. 6. Adularia. 7. Rock-crystal, transparent. 8. Topaz. 9. Bengal Corundum. 10. Diamond. Each of these is the name of an easily attainable mineral, and when any other mineral neither marks nor is marked by one in the above scale, it is said to be of that degree of hardness. By *racture* is meant the appearance of the broken part of a mineral, and it is usually said to be conchoidal, or hollowed like a shell; hackly, that is, with sharp points scattered over the fractured part, coarse, fine grained, uneven, smooth or splintery. When mineralogists speak of the *structure* of bodies they refer to the interior conformation, which may be compact, granular, fibrous, foliated, or laminated, that is, capable of being split into leaves, or laminæ; porous, or earthy. The degrees of *transparency* until opacity is reached, are expressed by the terms transparent, semi-transparent, translucent, and translucent on the edges. The *lustre* of minerals is characterised by the terms vitreous, or glassy, resinous, metallic, nacreous or pearly, and adamantine.

We recur to the subject of Crystallography, which has been defined to be the doctrine of the relations of crystalline forms. The circumstances from which crystallisation results, have been of late years subjected to much investigation, and the question is interesting as well with respect to theories of crystallography, as in relation to inquiries into the history of rocks in which crystallised minerals are found embedded. It is now ascertained that electricity is the great agent that determines the forms of crystals; but researches on this head are still going on, and it is expected that information of great interest will in the end be obtained. Writers divide the forms which crystals assume into *primary* and *secondary*, the latter being derived from the former. The primary forms are said to be six, and consist of the Cube, a solid figure of six sides, each side being a square of equal superficies; the Prism, a solid figure of six sides, the length of four being greater than the dimensions of the other two; the Rhomb, a solid equilateral oblique parallelogram: and combinations of these. Out of these the secondary forms are derived with more or less complication. It is often a work of some difficulty to enucleate the primary form from out of the usual form of the crystallised body. It is surprising, however, to see the identity of the primary form in the same mineral, no matter from what quarter of the world it may have been brought back, nor under what diverse secondary shapes it may be hidden. An instrument called the Goniometer, is of great use in all crystallographic investigations, by enabling the inquirer to measure exactly the angles of a crystal. We have thought it right to say thus much on the subject of crystallography, but to go fully into this branch of the science at present would only confuse the reader of these papers, and would require more space than we can properly devote to the matter here.

Minerals are divided into three classes—earthy, metallic, and inflammable.

### Class 1.—Earths.

There are eleven varieties of pure earths, namely: *Silica, Alumina, Calcia, Magnesia, Soda, Potassa, Zinconia, Glucina, Yttria, Barytes,* and *Strontia.* It is proper to inform the reader that these elementary earths have been proved to be oxides, that is, a combination of oxides with a metallic base; but as the metals are never found in a pure state, and are obtained only with great difficulty by means of chemical agents, it has been thought better to consider these oxides as pure earths, especially as they or their salts are found in great abundance.

Of all mineral substances *Silica* is the most abundant; there is scarcely a cubic inch of earthy matter in which it is not to be found. It is opaque, white, without smell or taste, and has a gritty feel. It is only very slightly soluble in water, and it requires a strong heat to fuse it. Its specific gravity is about 2·7. The purest form in which it occurs in nature is rock crystal; but it is met with in an extraordinary number of varieties. The generic name for the native forms of silica is Quartz or Silicite. It occurs both massive and crystallised; the primary form of the crystal is a rhomboid, but the commonest shape is a six-sided prism acutely terminated. Its fracture is conchoidal; 7 is the degree of its hardness. Two pieces rubbed together in the dark give out light, and emit a peculiar odour. Its lustre is sometimes vitreous, sometimes resinous. Some kinds are transparent, others perfectly opaque. Its colours, by admixture with other substances, are innumerable, but when pure, it is quite colourless It has been found impossible to fuse quartz by itself, but when soda or potassa is added it fuses readily, and forms that useful commodity, glass. The stones called Cornish and Bristol diamonds, are crystallised specimens of transparent quartz, but the finest crystals are found in Madagascar, and in France. Numerous names have been given to quartz in its different forms, some of which we proceed to notice.

*Amethyst*, is a purple quartz extensively used as an ornament It occurs uncrystallised as well as in crystals. It contains a slight quantity of alumina and iron. It is by no means an uncommon mineral, but the most valuable specimens come from India, Persia, and Siberia.

*Yellow or Smoky Quartz* is generally termed Cairngorm stone from its being found in large quantities in the mountain of that name in Aberdeenshire. A good deal is brought from Hungary, and hence it is sometimes called Hungarian topaz.

*Rose Quartz* is supposed to derive its colour from manganese. It is found massive and crystallised in Spain, France, Greenland, and America,

*Blue Quartz* also occurs massive and crystallised; the edges only are transparent. It is found near Salzburg in the Tyrol.

*Green Quartz* has been found in translucent prisms in Peru. When opaque and massive, green quartz is called *Prase.* That division of siliceous stones containing a large proportion of water, has been called hydrates of silica, or hydro-silicites. In this division the *Opal* and its varieties are placed.

*Common Opal* has a vitreous or resinous lustre, and is found of several shades of colour. Hungary and Saxony are the places where the best specimens come from.

*Precious Opal* is also found of various shades of colour, but it possesses the quality for which it is much prized, of exhibiting from the interior a play of colours at the same time. It scratches glass, but is easily frangible. Its specific gravity is about 2·07. It contains from 10 to 15 per cent. of water. The Hungarian specimens are in the highest estimation.

*Fire Opal* is closely allied to the last, only red is the sole colour reflected from within. This variety has been found in Cornwall.

*Semi Opal* is quite opaque; it is formed of four or five colours.

*Wood Opal* is a curious variety occurring in Hungary, in which a fibrous appearance is remarkable.

*Hydrophane* is another curious variety. It does not exhibit the play of colours seen in the precious opal until it is immersed in water. Klaproth found by analysis that its proportion of water is less than the other opals, and it contains a little alumina.

Other varieties of opal are called Hyalite (found at Meuil-montant, near Paris); Cacholong (a white opaque opal found on the banks of the Cach, in Bucharia); Opal Jasper, and Geyserite, or siliceous sinter, a deposit of the Iceland geysers. The best known of the minerals in this division is *flint*, the usual colour of which is grey, but the hue is sometimes red, yellow, brown and black. Flint nodules are found in amazing quantities embedded in chalk; it often takes the form of sponges, echinites, &c. It is rather harder than quartz, and is easily broken into angular fragments; its

fracture is conchoidal. Analysis show that it contains slight portions of lime, alumina, and oxide of iron. It is not nearly so much used as formerly, since percussion caps are employed to ignite the powder in fire-arms, except in the manufacture of glass, china, and porcelain.

Another important division of siliceous minerals is that formed by the alumino-silicites, by which *chalcedony* and its varieties are signified: common chalcedony occurs in numerous uncrystallised shapes, nodular, botryoidal, stalactitic and amorphous, and its colours are also numerous. Its lustre is resinous or waxy; it is harder than flint, infusible, and semi-transparent. It is found in all parts of the world; the finest specimens have been brought from Siberia and Hungary. Cornwall has furnished both stalactitic and blue specimens.

*Onyx* (from a Greek word meaning a finger nail) is a chalcedony consisting of alternate layers of light and dark. The fine effect of cameos is principally owing to their being made out of this stone; the figures being cut in the light band with the dark layer as a back ground. The finest known cameo is an antique in the Royal Library, Paris. It has four layers, represents the apotheoses of Augustus, and measures eleven inches by nine. *Sardonyx* consists of *sard*, a red brown chalcedony, with layers of white.

*Heliotropo*, or bloodstone, of a dark green colour with red spots, is found in Iceland, Siberia, and Scotland.

*Plasma* has also a dark green ground, but the spots are yellow and whitish. It is transparent; found in Moravia.

*Carnelian* (from *Carnis*, flesh, because it is chiefly of a flesh colour) is a stone well known from its being frequently used as an ornament. Many of the antique cameos and intaglios are made of carnelian. It is often of a white colour. The stone of commerce is principally brought from Japan.

*Agate*, also much used when under the name of Scotch pebble. Mocho stones and moss agates as an ornament. It is found principally in rocks of igneous origin or on the sea-shore. In the rock it lies imbedded in rounded nodules. It is nearly opaque, with a waxy or resinous lustre. To account for its origin it has been supposed that silica in a state of solution has poured into the cavities with which plutonic rocks abound, and this hypothesis is countenanced by the appearance of those stones which have been accidentally cut in a vertical section. The orifice where the siliceous solution has entered, and the way in which it has spread itself, in order to fill the hollow, may be clearly seen. The figuring of the agate is often very beautiful, assuming the shapes of fortifications, mosses, ribbon, &c. A vast quantity of these stones is brought from a place near Treves in the Prussian Rhenish dominions. The hill of Kinnoul at Perth, contains a great number.

*Jasper* is of a rich red colour, often marked with veins of crystal, and taking a high polish. It is mentioned in the Bible. It is found on the coast near Arbroath in large quantities, and a good deal is found in Egypt. *Hornstone* and *Chert* are species of compact quartz yielding a little alumina on analysis.

Another class of siliceous minerals is constituted of silica as the chief ingredient, alumina, lime, and sometimes potassa. It embraces Analcime, Leucite, Chabasite, Laumonite, and Apophyllite, minerals which, as they are not very often met with, we shall not pause to describe, except the last.

*Apophyllite* is a crystallised mineral with a lamellar structure, of a white or grey colour, with an occasional tinge of red or green. It is sometimes opaque, but its usual character is transparent. It is found either in mines of iron and lead, or in the cavities of igneous rocks. Its composition is silica, lime, and potassa. All the minerals of this class are fusible before the blow-pipe.

We now approach the *Garnet* division, distinguished by having, in addition to silica and alumina, a large quantity of oxide of iron or oxide of manganese, and sometimes both. The garnet, a well known precious stone, is one of numerous varieties bearing efficient names. The precious garnet is called Almandine; the black, Melanite; grass green, Grossularia, &c. It occurs massive, granular, and crystallised. The primary form of the crystal is a cube, but it is commonly found as a rhomboidal dodecahedron. It is transparent with a vitreous or resinous lustre, uneven fracture, and a hardness varying from 6 to 7. The common garnet differs little, except in hardness from the precious. It is an abundant mineral, found in granite and in some kinds of slate. Specimens have been met with in Styria two pounds in weight. *Cinnamon Stone* is closely allied to the garnet; it is of a bright red or orange yellow, and is massive. It is found in Ceylon. *Lievrite* is another mineral of this division, of rare occurrence, called after its discoverer. It contains no lime, and is found only in Corsica; its colour is black or brown.

Another class of siliceous minerals, in which lime forms about one-fifth, and alumina one-third, comprises the following species:—

*Ido-crase*, or *Vesuvian*, occurs both massive and crystallised. Its usual colour is yellow or green, but it is found of various shades of black, brown, grey, and blue. Its lustre is vitreous, resinous, and it is translucent and transparent. Its crystals, which are sometimes large, have a double refraction, and the primary form is a square prism. The degree of hardness is 6. It is chiefly found in volcanic countries, and it is seen in the primitive districts of the Alps and Siberia. Like all the minerals of this class it is fusible before the blow-pipe. It contains oxide of iron and a trace of manganese.

*Prehnite* also occurs crystallised and massive. The primary form of the crystal is a right rhombic prism; when heated it becomes elastic. Its colour is green, grey, and white; it is both transparent and translucent, lustre vitreous, and is hard enough to scratch glass. The massive varieties are globular, botryoidal, and stalactitic. It changes before the blow-pipe into a white scoria. It was first found at the Cape of Good Hope; fine specimens come from Greenland, and it is found in France, Cornwall, and Scotland.

*Wernerite*, *Heulandite*, *Thomsonite*, and *Scolezite*, have pretty nearly the same constituents. The last occurs in very minute crystals, or massive.

*Epidote*, *Thallite*, or *Pistacite*, occurs crystallised, granular, and massive—both transparent and opaque, with a hardness of 6 to 7. Its lustre is vitreous, and its colour various shades of green, grey, yellow, and blackish red. It is found only in the primitive rocks, but is extensively scattered over the world; in the East Indies and North America, in England, France, Switzerland, and Norway.

*Toisite* is coloured yellow and red, and is found in Carinthia and the Tyrol.

*Indianite*, a rare mineral, found in granular masses. Hardness 5. Colour white or grey, translucent, infusible before the blow-pipe; has a shining lustre. It is found along with garnet, felspar, and hornblende.

*Oxinite*, usually found in prismatic crystals with sharp edges, the primitive forms being a double oblique prism. Its colour is brown, sometimes blue; its lustro vitreous; its hardness 6 to 7. It is sometimes transparent. It is a scarce mineral; it occurs in the Cornish mines.

*Lazulite*, *Lapis Lazuli*, from which the pigment ultramarine is obtained, is found in Persia and China. It occurs both massive and crystallised; primary form of crystal a cube; hardness 5 to 6. It is translucent and opaque; its colour being blue.

*Dipyre*, or *Leucolite*, a mineral of rare occurrence, its colour being reddish white. Found in the Pyrenees.

*Tourmaline*, a mineral of many colours, which melts into a pale glass before the blow-pipe. It occurs crystallised in prisms, some varieties being transparent, others opaque. Black is the commonest colour. The six-sided prismatic crystals are electric.

The *Clay* division consists of numerous varieties, some hardened into a stone and then called slate, others soft and plastic. A good deal of alumina is found in the composition of clay. It is a very useful mineral, employed extensively in earthenware, brick-work, &c.

*Shale* is a species of clay occurring in the neighbourhood of coal. It is geologically rich in the fossil remains of plants.

*Lithomarge* and *Cimolite* are also argillaceous minerals, as well as *Mountain Meal*, a rare mineral found in Tuscany, so light that it swims in water.

We shall now consider that division of Siliceous minerals termed Baryti-Silicite; it contains only two varieties, Harmotome and Amianthoide.

*Harmotome* is a mineral generally found in yellowish white, or brownish grey crystals intersecting one another. It is sometimes, however, found massive, and is commonly attached to zeolite. It contains about 20 per cent. of barytes, and nearly 50 per cent. of silica. Hardness 4; lustre vitreous. The primary form of the crystal is a right rhombic prism. Acids have scarcely any action upon this mineral; before the blowpipe it fuses into a clear glass. It is found at Strontian in Scotland, and in Germany.

*Amianthoide* (a word signifying *like amianthus*) bears some resemblance to that variety of asbestos, after which it is named. It is flexible and has a greenish grey colour. Five or six per cent. of barytes have been found in it.

The next division is constituted by *augite* and its varieties; they contain a large proportion of magnesia and lime, and are hence called Magnesi-Calc-Silicites.

*Augite* is a very important mineral in a scientific point of view, and it has received much attention from mineralogists and geologists. *Pyroxene* (or augite in its limited sense) is a crystallised mineral, found in a great number of plutonic rocks, that is, rocks whose present condition is accounted for by fire. It is opaque, of a dark brown colour; its crystals are eight-sided prisms, with diedral summits. It is found plentifully in all volcanic regions. Mitscherlich obtained the crystals artificially, by submitting a mixture of silica, lime, and magnesia, to fuse in a porcelain oven. Its crystals are found artificially formed amongst the scoriæ of foundries.

*Hornblende;* experiments have shewn that this mineral, abundantly distributed over the globe, is uncrystallised augite. It is always massive, of a brown colour, and disseminated in many rocks, such as syenite, porphyry, &c. When the materials have been rendered fluid from heat, a rapid cooling has crystallised them into augite, and by a slow cooling, hornblende has been formed.

*Diopside* has a pale green or greyish white colour; hardness 5. lustre vitreous; the blowpipe melts it into a semi-transparent glass. Varieties have received the names of Backalite and Fassaite.

*Hedenbergito* is a rare augite, occurring both massive and crystallised in Bohemia. It is of a greyish green colour, and sometimes black.

*Sahlite*, a variety of augite containing protoxide of iron.

*Diallage*, a variety distinguished by its nacreous lustre; colour bronze yellow; seldom found in perfect crystals.

*Hypersthene* is not unlike diallage in appearance and character. The latter, however, is fused with difficulty even with borax, but hypersthene readily forms a clear glass both with borax and on charcoal.

Another division has been denominated Magnesi-Silicite; it comprehends the following minerals :—

*Tremolite* occurs granular, fibrous, asbestous, and glassy. In colour greyish white, sometimes yellowish or greenish; when subjected to a strong heat its colour disappears, perhaps on account of the carbonic acid being dissipated, of which it contains a considerable quantity. It is brittle and shining. Specific gravity 2.8. It is found in limestone in the Highlands, and on the basalt of the Castle rock, Edinburgh.

*Actinolite* (that is rayed stone) is generally found in longish crystals of a green colour, arranged in the form of rays, but it occurs also fibrous and massive.

*Schiller-spar* is a crystallised mineral, having various shades of green, translucent on the edges only—specific gravity 2.69. It is generally met with in Serpentine; Cornwall, Piedmont, and Saxony are some of the localities where it is found. It is scratched by quartz, but scratches calcareous spar.

*Anthophyllite* is usually massive, lustre shining, colour yellowish grey, verging to brown. It contains the oxide of iron and manganese. The primitive rocks of Norway inclose a good deal of it.

*Kyanite* or *Disthene* occurs both massive and crystallised of a white, yellow, blue, or green colour: lustre vitreous, pearly, transparent, translucent. The primary form of the crystal, which is hard enough to scratch glass, is a doubly oblique prism. Specific gravity 3·6. Infusible before the blow-pipe except with borax. It is found in most of the primitive mountains of Europe, and on the Continent of America.

*Staurolite* or *Grenatite*, occurring only in the form of crystals, the primary crystal being a right rhombic prism; transparent, translucent, and opaque; lustre vitreous, fracture conchoidal; will scratch quartz, but not easily; colour reddish brown. It contains a very small proportion of manganese; specific gravity 3·7. It is found in the primitive rocks of Europe and North America.

*Asbestos* may almost be said to be applied rather to the form of a mineral than to form a distinct variety. Several of the preceding minerals, such as actinolite, tremolite, &c., take this shape, which is a fibrous mass made up of long hair-like crystals side by side. The name is derived from a Greek word signifying indestructible, because the ancients were able to weave a sort of cloth out of this mineral-flax, in which they wrapped dead bodies before they were burned, and thus the ashes were prevented from mixing with the common ashes of the pile. Common asbestos is of a greenish or greyish white, and without much flexibility.

*Amianthus* is a fine silky mass, readily fraying under the finger, of a white or grey hue. The most beautiful specimens have been found in Savoy; Cornwall, Scotland, and Saxony, are localities where it is found. It is sometimes used as the wick of a lamp in America.

*Mountain Cork*, mountain leather, and mountain paper, are naturally interwoven varieties of asbestos, the first of which is light enough to float in water, and the two latter are named from their appearance. All the varieties of abestos are fusible before the blow-pipe.

We now approach the last division of this class, the Potassi-Silicites.

*Obsidian* was well known to the ancients, who used it for mirrors and for carved work. Intaglios were made of it; and we are told that Augustus dedicated four elephants of obsidian to the Temple of Concord. The Egyptians used it in their statuary, and the inhabitants of South America have constructed knives of it. It is of compact structure, with conchoidal fracture, brittle, opaque, and transparent on the edges, colour black of various shades; scratches glass. It intumesces before the blow-pipe, and

then forms a transparent glass. It is supposed to be of volcanic origin, and is found in various parts of the globe. Specific gravity 2·3.

*Jade* or *Nephrite*, is found in masses of a green colour, having a compact structure. It is very tough, and has a hardness of 7. It is translucent on the edges, and has a specific gravity of 3. The inhabitants of savage countries, where it is met with, are in the habit of making weapons with it, such as arrow-heads, axes, &c., hence it is sometimes called Axe-stone.

*Gabronite* and *Petalite* are minerals in the same class, not often met with.

The next Earth on our list is ALUMINA; it enters into the composition of a great number of minerals. It is sometimes called argillaceous earth. When pure, it is white, powdery, light, insoluble in water, without taste or smell. Exposed to a strong heat it will melt into a clear colourless glass. It is a large ingredient in all the clays; and it is of greater importance than silica in earthenware, porcelain, and bricks.

*Alum Stone* is found in Italy and Hungary, and is used in the preparation of the alum of commerce. It occurs massive and crystallised; the crystals being smooth and shining, found in the cavities of the massive variety. Sulphate of alumina is the principal ingredient; potash is generally present, and sometimes silica.

The Fluor-Aluminites comprehend Topaz and Kollyrite. *Topaz* is a composition of fluoric acid, alumina, and silica, occurs massive and crystallised, easily scratches quartz. Colour white, yellow, bluish, and greyish; lustre vitreous; transparent, translucent. Specific gravity 3·49; melts with borax into a glass; primary form of crystal, right rhombic prism. With friction, or when heated, it becomes electric. It occurs in the primitive rocks of many parts of the world. We need scarcely inform our readers that the common topaz is a gem much valued for ornamental purposes, though it is not to be confounded with the oriental topaz, a much more precious gem.

*Kollyrite* is of a light or dark yellow, and occurs massive and crystallised; it is found in Saxony, Siberia, and France.

*Pycnite* occurs massive and crystallised, the crystals being hexahedral prisms of a straw-yellow colour, becoming electric with friction.

To the Potassi-Silica-Aluminites belong the following:—

*Mica* or *glummer* is generally met with in a laminary form; colour greyish yellow, or greenish grey. It is sometimes crystallised, the primary form being a rhomboid, but it is usually found in equi-angular six-sided tables. It has a semi-metallic lustre, and flexible when laminar. Specific gravity 2·6. It enters largely into the composition of the rock, named by geologists Mica-schist, which is placed next to granite amongst the primitive rocks. It very often holds garnets and other crystals. In Siberia it is used in windows instead of glass, so fine and transparent are the sheets into which it is severable. It is distinguishable from talc, to which, however it bears a strong resemblance, by its greater brilliancy.

*Andalusite* (from Andalusia in Spain, where it was first found) occurs both massive and crystallised, of a flesh-red colour; the crystals are four-sided prisms, translucent on the edges. It is only found amongst primitive rocks, accompanying quartz and felspar.

*Pinite*, a mineral of a grey or red colour, found massive and crystallised; the primary form being a rhomboid, but it occurs in hexagonal prisms. It scratches gypsum, but is scratched by fluor spar. It is opaque; specific gravity 2·7. It melts before the blowpipe into a glass. Cornwall, Saxony, and France are amongst its localities.

*Bucholzite*, a mineral of a brown colour, not much known, belongs to this division.

Amongst the Potass-aluminites are the following:—

*Lepidolite* is sometimes massive, but usually composed of thin scales of a semi-metallic lustre. Colours, rose, flesh-red, purple, grey, and greenish. Specific gravity 2·8. Before the blowpipe it melts into a white globule, semi-transparent. It contains a small portion of lithia. It has been found in Moravia, Russia, Sweden, and North America.

*Nacrite* is usually found in granite, or in company with mica slate. Lustre pearly (hence its name) translucent; hardness 2·7. Specific gravity 2·7. Its crystals are four-sided prisms. Some varieties contain no potash, but usually potash is detected in considerable quantities. It is found in Wicklow, Ireland, Moravia Bohemia, &c.

The Hydro-potass aluminites comprehend the following—

*Haüyore* or *Latialite*. The first name was given to it in commemoration of the distinguished crystallographer, the Abbé Haüy. Occurs massive, granular, and crystallised; it is brittle, has a hardness of 5 to 6, with a specific gravity of 2 to 3; colour blue or bluish green. The usual shape of the crystallised variety is a rhombic dodecahedron, the primary form being a cube. It is found in the interior of lavas and rocks in volcanic countries.

*Gieseckite* has only been found in Greenland. It occurs in six sided prisms, of a brown colour.

*Felspar*, a class of minerals very widely distributed over the globe, whose composition, though varying in the proportions, is made up of silica, alumina, potash, and lime, the last being in a very minute quantity. Felspar occurs both crystallised and massive; the primary form of the crystal being an oblique rhombic prism. The colours run through various shades of red, green, grey, and white. Hardness 6. Specific gravity 2·5. It is transparent, translucent, or opaque, with a vitreous lustre, and a conchoidal fracture. It is an abundant mineral. It is a constituent of granite along with quartz and mica; it enters into the composition of gneiss, and it constitutes alone many large rocks. With hornblende it forms syenite, and of many kinds of porphyry it is the principal ingredient.

*Adularia* or moonstone is a pure limpid variety of felspar, taking its first name from Adula in Switzerland. It is used by the lapidaries, having a splendid appearance when polished. The finest specimens come from Ceylon, but it is found at Snowdon, North Wales, in the granite of Arran, and at Mount St. Gothard.

*Labrador Felspar*, so named because first found on the coast of Labrador. It occurs in rolled or imbedded crystalline masses. Hardness 5 to 6. Specific gravity 2·7. Its colour is white or grey, lustre vitreous, and it is translucent. On account of its rich iridescency it is used by the lapidaries for ornamental work.

*Scapolite* is found in Saxony, Norway, Sweden, and Greenland. It is of a red colour, has a pearly lustre, and when crystallised, it has the form of an eight-sided prism.

*Claolite*, the last variety of felspar that we need mention, is found either blue or red. It usually occurs massive; its specific gravity is 2·6. It is found in various parts of Norway.

The next division includes the calc, silica, aluminites.

*Meionite* is met with near Naples and Rome, in eight-sided prisms of a whitish colour, and shining lustre.

*Sommite* occurs in the same localities, in grains, or in small hexagonal prisms, the primary form being a rhomboid. Specific gravity 2·36. It scratches glass. A transparent bit put into nitric acid becomes cloudy, hence its name, *nepheline*, from a Greek word.

*Chiastolite* has a greyish white colour on the outside, and

## REFERENCES TO PLATE

A A, Longitudinal iron framing of the machine. It is continued round the fire-box by a cross piece, which carries the driver and assistant's platform, P' P'.

B B, Cross beam of wood, into which the ends of the iron side-frames are bolted. It carries the buffers or pads, B' B', at its extremities.

C, That part of the boiler which contains the fire-place or furnace, K.—Shown in fig. 3.

D, The steam dome, into which the receive-branch, S', of the steam-pipe, S S, rises, as shown in fig. 3.

D' D', Driving axle, upon which the driving-wheels are made fast.

E, First safety-valve, weighted by the lever, w', and the spring-balance, z'.

F, Second safety-valve, weighted by a screw and spring, and enclosed so as be beyond the control of the driver.

G G, Tubular compartment of the boiler.

G', Guards for clearing the rails of stones and the like, which may be left upon them by accident or otherwise.—Fig. 1.

H H, Smoke-box, surmounted by the chimney of the engine.

I, Blast-pipe, for escape of the used steam from the cylinders into the funnel or chimney. It communicates, at its lower end, with the eduction-pipes of both cylinders, as shown in fig. 5.

J J, Branches of the steam-pipe, S S, leading to the valve-boxes, V V.

K, Fire-place, contained in the fire-box compartment of the boiler, C, as shown in figs. 3 and 4.

L, L', Enlarged and squared ends of connecting-rods, Q.

M, M', Forward eccentric pulley and rod.—See fig. 7.

N, N', Backward eccentric pulley and rod.—See fig. 7. There are four eccentrics, viz., one pair for each cylinder; but only one pair is shown in the drawings. The pairs are fixed at right angles to each other, and to their respective cranks, so that the valves being worked by the eccentrics, M or N, the engine will have a forward or retrograde motion.

O, Handle for working the regulator valve, v.—Shown in fig. 3.

P, Piston-rods. The cross-heads work in horizontal guides, m m, so as to insure their motion in the exact direction of the axis of the cylinder.

Q, Connecting-rods. These are connected with the piston-rods by iron straps, e', and transmit the motion of the pistons to the cranks, R R.

Q', Lever for communicating the motion of the eccentric-rod to the valve-rod. It is fixed, at the middle of its length, upon a cross-axle, as shown in fig. 7.

R R, Cranks of the driving-axle, D' D', placed at right angles to each other, as shown in fig. 4.

S S, Steam-pipe. It passes horizontally through the cylindrical compartment of the boiler, till it joins the branches, J J, in the smoke-box, and the branch, S, in the fire-box.

T T T, Iron knees, by which the boiler is fixed upon the longitudinal iron framing of the engine.—Figs. 1 and 3.

U U, Springs resting at a a, upon the axle-boxes, by means of two vertical pins passing through holes in the side framing of the engine. The upper ends of the pins rest against the springs, and the lower ends on the axle-chairs, so that the weight of the engine is thus transferred to the wheels through the springs.

U', Water-tank of the tender.—See figs. 1 and 2.

V V, The valve-boxes. In these the slides work, as shown in fig. 8.

V', Rod connecting the handle, X, with the lever, X'.

W, Driving-wheels, which are fast upon the crank-axle, D' D'.

W', Steam-whistle, shown in section; enlarged by fig. 11.

X, Handle communicating with the lever, X', by the rod, V'. By this the engine-driver throws the eccentric rods into gear with the lever, Q', which works the slides by means of the arms, y and z, and their connecting links, as shown in fig. 7. In the position shown, the forward eccentric-rod, M', is in gear; but the handle being pulled back to the position, P', the gab of the eccentric rod is raised out of gear with the lever, Q', and being still further pulled back to R', the backward eccentric-rod, N', is lowered into gear with Q', and the motion of the engine is reversed.

Y Y, The steam cylinders, shown in end elevation in fig. 6, and in cross section in fig. 5. Fig. 8 is a longitudinal section through the valve-box, on a scale of one inch to the foot.

Y', Long handle for working the break of the tender.—See b' b'.

Z, Feed-pumps, worked by the piston-rod cross-heads, and connected with the water-tank of the tender through the pipes, c c, and with the boiler by the pipes, c', fig. 3.

Z', Handle and rod connected with the safety-cocks of the pumps. By these cocks the driver can ascertain whether the pumps be producing their proper effect, by their giving a jet of water when opened.

a, Axle-boxes, in which the axles revolve. These slide vertically, between two guides.—See U U.

b, Bars of furnace grate.—Shown in fig. 3.

b' b', Break of the tender, which is brought into action by a long hand-lever, Y', attached at n.—See fig. 1.

c c, Suction pipes, connecting the feed-pump, Z, with the water-chest of the tender.

d, Door by which fuel is thrown into the fire-place, K.

e, Eduction port, by which the used steam escapes from the cylinders into the blast-pipe, I.—Shown in fig. 8.

e', Iron straps, by which the connecting-rods, Q, are attached to the piston-rod cross-heads.—Shown in fig. 4.

f, Guide-blocks, fitted betwixt the guide-bars, m, in which they slide, in obedience to the motion of the piston, whose cross-head passes through them.—Shown in fig. 9.

g, Flanges cast upon the cylinder covers, for fixing the ends of the guide-bars, m m.—Shown in fig. 4.

h h, Frames to which the other ends of the guide-bars, m m, are fixed.—Shown in fig. 6.

i i, Iron straps, attaching the ends of the piston-rod socket to the cross-head.

k k, Water space between the sides of the fire-place and interior of the boiler.—Shown in figs. 3 and 4.

l, Key and gib for fixing the straps, n, upon their connecting-rods.

m m, Guide-bars, between which the guide-blocks, f, slide.—See P.

n, Iron straps, by which the connecting-rods are attached to their respective cranks, R R.—See figs. 3 and 4.

o, Connection of the feed-pumps with the piston-rod cross-heads.—See fig. 4.

p, Partition between the fire-box and tubular part of the boiler.—Shown in fig. 3.

q, Front plates of fire-box, into which the other ends of the flue-tubes are fitted, water-tight.—Fig. 3.

r, Slide-valve rod, connected with the centre-lever, Q'.—Fig. 7.

s, Regulation-valve spindle, connecting the valve, v, of the steam-pipe, S S, with the handle, O.—See fig. 3.

t t, The flue-tubes of the boiler, extending between the plates p and q.—Fig. 3.

u u, Iron straps, by which the cylinders are fastened to the frame of the engine, and to each other.—Figs. 3 and 5.

v, The regulator-valve of the steam-pipe, S S, worked by the handle, O.—See fig. 3.

w, Water-guage, a glass tube, fixed at top and bottom into brass sockets, which communicate with the interior of the boiler.

w', Weighting lever of first safety-valve, E.—See figs. 1 and 3.

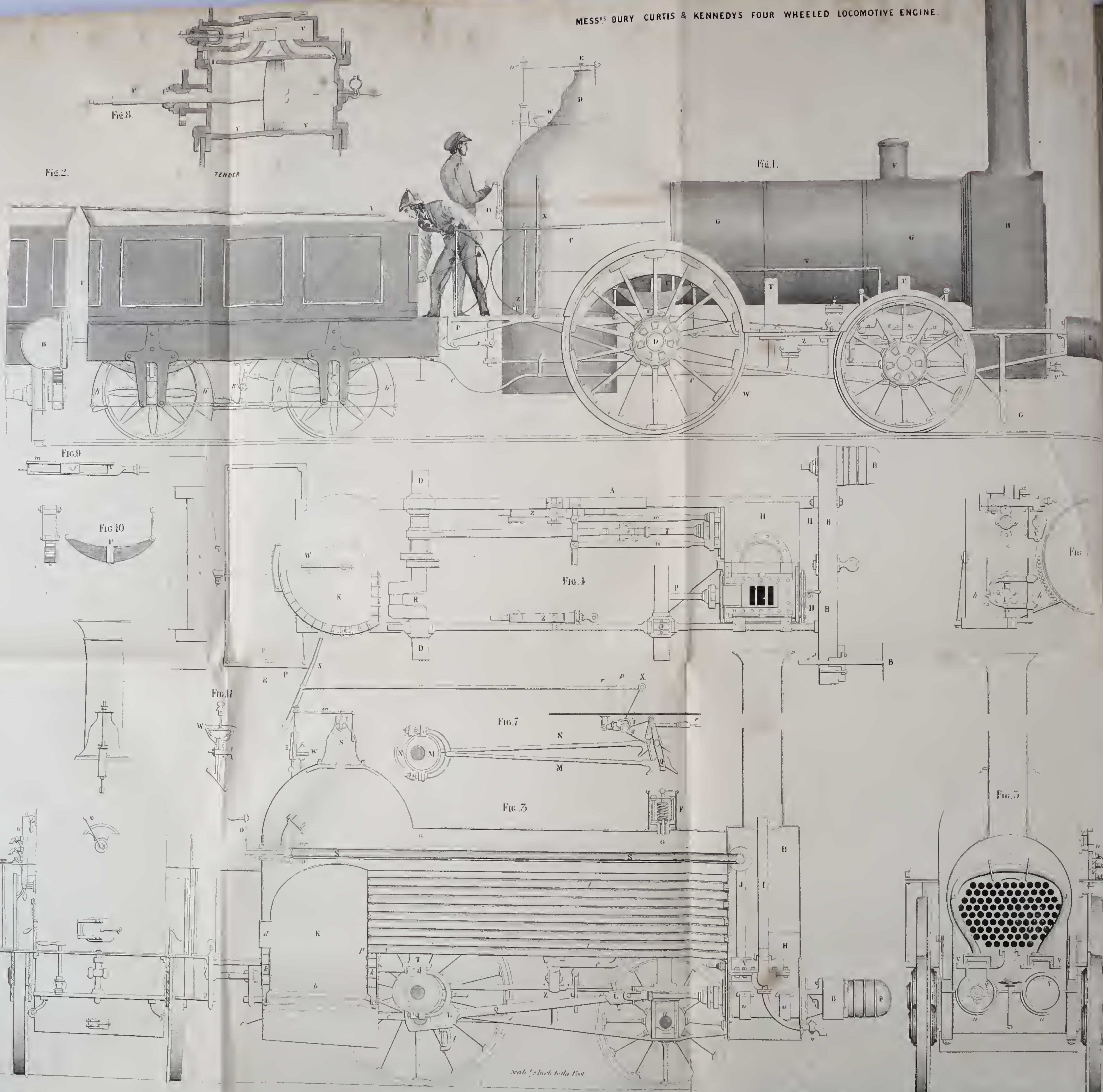
x, Slide-valves (see fig. 8) connected with the eccentrics upon the crank-axle, by means of the eccentric-rods and centre-levers, Q'.—Shown in fig. 7.

y z, Reversing levers, through which the eccentric-rods, M' N', are worked by the handle, X.

y', Pipe and cock, by which water collecting in the cylinder is let off.

z z, Coupling links, by which the tender is attached to the engine.

z', Spring-balance, by which the first safety-valve, E, is weighted. A screwed rod passes from it through the lever, w', and upon this a nut is placed to regulate the tension of the balance-spring, as required.



is black within. It is found in rectangular prisms, and is so thickly diffused through one of the Cumberland slates, that it is called chiastolite slate. It is by no means a common mineral; it is found in Spain and the Pyrenees.

*Sadalite*, a rare mineral, of a light-green colour, found in Greenland and Vesuvius.

*Talc* is crystallised and massive. It separates into thin plates which have no elasticity, but are flexible. It is found of a white, red, grey, and green colour, is both transparent and opaque, has an unctuous feel, and a pearly lustre. Specific gravity 2·7. The primary form of the crystal is a rhomboid. Indurated talc is of a greenish grey colour, slightly translucent. The crystallised variety is found at Gleusilt, in Cornwall, and in the Tyrol.

*Corundum.* This is the generic name for minerals differing very materially in appearance and value, for amongst them are the *ruby*, sapphire, emery, &c. The primary form of the crystal is a slightly acute rhomboid. Common corundum, or adamantine spar, has great variety of colour, but it is usually greenish or greyish. It is found in crystals in many parts of the East, and it is extensively used in cutting and polishing precious stones.

*Emery* is usually grey, granular and massive, has a specific gravity of 3 to 4. Like corundum it is used for polishing hard substances. It is chiefly found in the East Indies.

*Ruby.* This valuable precious stone is of a red colour sometimes with a tinge of violet. It is usually met with in six-sided prisms. The richest specimens are brought from Ceylon and Pegu; but it is found also in Europe.

*Sapphire* is harder than the ruby; it has also a variety of colours bearing different names; the emerald is green; the oriental topaz, yellow; the oriental amethyst, purple; the oriental sapphire, blue; there is also a white variety, specific gravity 4. It is found in rolled masses and crystallised; the usual form of the crystal being a six-sided prism with a variety of terminations. It has the property of double refraction. With borax it melts into a colourless glass. The most valuable specimens come from Ceylon and Persia.

*Automalite* is found in a crystallised form in Sweden, it is of a dark green colour.

*Ceylonite* is found in grains, and in octahedral crystals. It is of a very dark green colour almost black. It is found in Ceylon, in Italy, and on the Rhine amongst trap rocks.

*Salaamstone* is of various hues of red, granular, and in hexahedral prisms. It has only been found in Hindostan.

The members of the next division have been called Ferro-Potass—Aluminites.

*Schorl* is of a dark brown colour passing into dark green; opaque, and of a shining lustre. It is found disseminated and crystallised in prisms. It is met with in the primitive rocks of Europe; and bearing some resemblance to tourmaline, since mineralogists have called it opaque tourmaline.

*Killinite* occurs both crystallised and massive, of a greenish or brownish yellow tint; it is translucent and opaque, a lamellar structure, and a vitreous or glimmering lustre. It is found at Killiny near Dublin; hence its name.

*Rubellite* is of a red or pink colour; occurs in crystallised masses, not differing much from tourmaline with which it is sometimes found.

*Melilite* occurs both crystallised and massive; colour a reddish or greyish yellow, translucent and opaque. It is found in Italy, Bohemia, and Hungary.

*Spinellane* is an uncommon crystallised mineral of a yellowish or bluish colour.

*Mesotype* or *Natrolite* is found in plutonic rocks in Iceland, Scotland, &c. It seems both crystallised and massive, has a white colour, with shades of red, yellow, and grey, a vitreous lustre, and is transparent.

The last of the aluminites we shall describe, is a mineral called *Wavellite*, which occurs crystallised (the commonest form being a rhombic prism) and botryoidal, with a radiated internal structure. It is semi-transparent, has a shining surface, and its colour is white, greyish, greenish, or brownish. Specific gravity, 2·2. It is named after its discoverer, Dr Wavell, who found it near Barnstaple, Yorkshire. It has since been found in Greenland and South America.

The third of the earths before enumerated is Calcia or lime. It is one of the most abundant of animal substances. It has so strong an affinity for acids and other earths, that it is never found pure. It is however easily obtained pure by a chemical process, and it is then seen to be white, opaque, and inodorous; infusible by the greatest heat, having an acrid alkaline taste; specific gravity 2·3. If exposed to the air it absorbs moisture and carbonic acid and gradually falls to powder. The lime used for mortar is a tolerably pure alkali obtained by expelling the acid of the stone by heat, and then mixing the earth with water.

## ANALYSES OF LOCOMOTIVE ENGINES.

### CHAPTER I.

#### POPULAR DESCRIPTION AND DETAIL.

Example.—A four-wheeled Locomotive Engine, as constructed by Messrs. Bury, Curtis, and Kennedy, of Liverpool.

Notwithstanding the general simplicity of the locomotive engine, and the intense interest with which it is universally regarded, its mechanism and mode of action are still but imperfectly understood by a large portion of the myriads who are in the constant practice of availing themselves of its capabilities. We are not anxious to inquire into the cause of this dimness of knowledge; but request the indulgence of the professional engineer, while we endeavour to place in the hands of our non-professional readers, such a description of this favourite machine as shall render the arrangement of its parts, and their connexion and uses, intelligible to those who regard it only as a beautiful example of mechanical skill and adaptation. An explanation of this elementary nature may likewise have its use in bringing the subject directly before us; and enabling us to be more precise and succinct when we come to the discussion of the practical details of construction, and the mechanical laws which regulate the capabilities of the machine. In the meantime, however, we may premise, that although our description be general and popular, our drawings exhibit the latest improvements in form and construction adopted by Messrs Bury.

It is hardly necessary to observe, that a locomotive engine differs in many particulars from other steam-engines. The source of power—the principle of mechanical life—is a point of agreement; it determines the order to which the locomotive naturally belongs. But in this we have a new species, adapted to other purposes, and possessing different capabilities. The machine, as its name imports, is intended for locomotion—we need not say at what velocities; and in order that it may fulfil its purpose, it must carry along with it the fuel and water which are necessary to maintain its action. This condition implies compactness and lightness of construction, combined with the requisite power. To obtain these first, the engine and boiler are united together in the same machine; and the parts are made of much smaller dimensions in proportion to the power, than in other steam-engines. The requisite power is obtained by using steam of very high pressure—of such a pressure as will allow the steam-cylinders to be of small capacity; but in order to obtain steam in sufficient quantity and of sufficient pressure from a boiler which must also be portable, it was necessary to depart from the common form, and to adopt a mode of construction by

which the evaporative power of the boiler, that is, its power of generating steam would be greatly augmented. The condition of locomotion at high velocity in so weighty a mass as the lightest and most compact locomotive must be, implies, moreover, subjection to violent strains and shocks, which must as far as possible be provided against by strength and firmness in the framing together of the whole.

It may readily be conceived that locomotive machines did not at once start into their present state of approximate perfection, but have been gradually matured by successive modifications and improvements. Among the leading improvers in this department of mechanical engineering, we must place Mr Edward Bury, the head of the firm whose construction of engine we have selected on this occasion as an appropriate example for general illustration. It differs from the engines of most other makers, in having only four wheels, instead of six, and in a few other particulars which we shall have occasion to point out when we come to compare it with other examples of locomotive machines.

### Description of the Engine.

The principal parts of the engine are those which furnish the means of supplying the steam, and bringing into operation the elastic force residing in that agent. These are the boiler and its firing apparatus, and the steam-cylinders with their slides and pistons. In connexion with these may be named the cranks and wheels, by which the motion is transferred from the pistons to the machine itself.

Fig. 1 is a side elevation, showing the general appearance of the engine and tender-carriage. The use of this last is to carry the fuel and water required by the engine, and is so closely attached that the fireman can conveniently throw the coke upon the engine fire. A pipe also communicates between the water-chest upon it and the engine-boiler; through this the water is made to pass into the boiler by means of a forcing-pump, worked by the engine itself, whenever it is found necessary.

Fig. 2 is part of an elevation of the end of the engine, to which the tender-carriage is shown attached in fig. 1. It gives a complete idea of the general appearance of the end, the part cut away in the drawing being precisely the same as that shown.

Fig. 3 is a longitudinal section of the engine by a vertical plane passing through its axis. This shows the body of the machine, composed of three distinct compartments. That marked H on the left in front of the engine, and surmounted by the funnel is called the smoke-box. The next two compartments together, constitute the boiler: the middle one G G, from which the smoke-box is separated by the partition *p p*, is the boiler properly so called; and, the hinder one, in which is placed the box K, forming the fire-place of the engine, is denominated from that circumstance, the fire-box. Between the sides of the box K, and those of the compartment in which it is contained, there is left a clear space *k k*, which communicates freely with the middle compartment of the boiler, and is like it filled with water to the proper height when the engine is in operation. The top of the box K is made spherical, in order more effectually to resist the steam-pressure to which it is necessarily exposed. In the bottom is placed the grate, one of the bars of which is represented by *b*, and in the outside is the door *d*, through which the coke is supplied to the fire.

When the fuel in the fire-place is lighted, and the door shut, no more air is admitted, to support the combustion, than passes between the bars of the grate at the bottom; nor is the flame allowed egress except through a number of small tubes or flues, *t t*, which pass through the whole length of the middle compartment, thereby forming a communication between the fire-place K and the smoke-box H. The fire being thus completely shut up and surrounded by water, none of its heat is lost, except that portion which must, under all circumstances, be carried away by the gaseous products of the combustion. In the first place, a part of it is taken up by the water which occupies the surrounding space, *k k*. Afterwards, the flame divides itself among all the small flue-pipes *t t*, which are likewise completely surrounded by water; and thus only escapes into the smoke-box, after having communicated as much as possible of its heat to the metallic surfaces with which it comes into contact, and thence to the water in the two divisions of the boiler.

In this arrangement, we perceive that the heat of the burning fuel is applied with great economy. A large surface of water is brought into contact with it; and while the water surrounding the fire-place is heated and converted into steam by the heat which it directly absorbs from the incandescent fuel upon the grate, the water in the middle compartment of the boiler is, in like manner, heated and converted into steam by the inflamed gases which issue from the fire-place. In this arrangement we have an explanation of much of the astonishing power and efficiency of the locomotive engines of the present day. While it provides the requisite supply of steam, it allows the boiler to be made of the necessary strength, compactness, and dimensions.

The disposition of the flue-tubes of the middle compartment of the boiler is more fully shown by fig. 5. This is a transverse section of the engine, through the smoke-box, and consequently shows the openings of the flue-tubes. These are, in this instance, 96 in number, and are made of rolled brass, well soldered together at the edges, and drawn perfectly straight and cylindrical from end to end. They are, moreover, all tested to about 300 lbs. per square inch, internal pressure; and from this their power to resist compression is inferred. In the boiler, they are fixed by rivetting, water-tight at one end, in the front-plate *q q* of the fire-box; and at the other, in the partition-plate *p p*, through which they open into the smoke-box. As further security in fastening the tubes, steel rings or ferrules, made slightly tapered, are driven into their ends after rivetting, thus completely wedging them against the sides of the apertures in the tube plates into which their ends are received.

The tubular compartment of the boiler is itself cylindrical, and is therefore better adapted to resist the pressure of the steam than if its sides were rectangular. But this form does not extend to the fire-boxes. These are flat, except on the top; and would therefore be liable to be separated by the internal pressure of the steam, were it not that they are strongly bound together, all round, by bolts (as shown in fig. 3), which pass through holes tapped in both plates to receive them. These bolts, at the same time that they give solidity to that part of the boiler, which, on account of its form, is calculated to offer less resistance than the cylindrical parts, also serve to suspend the internal box K in its place.

Having thus described shortly the steam-generating apparatus, our next business is to point out the manner of applying the steam with effect, after it is produced.

In the upper part of the boiler is placed a large pipe, S S, called the steam-pipe. The end of this pipe, which passes into the dome-shaped part of the boiler, surmounting the fire-box, passes off by a branch, S′, nearly to the top of the secondary dome D, and which is occupied by steam, being completely above the water in the boiler. The extremity of the pipe is open; but at the point where it branches off from the main-pipe S S, there is a conical valve, *v*, which can be opened and closed at pleasure, and in any degree, by the handle O. To understand this distinctly, it is to be observed that the connexion between the valve and the handle is by a spindle *s*, which is fitted into a cylindrical brass socket on the end of the valve. In this socket a spiral groove is cut, to receive a corresponding spiral feather, formed upon the interior of the casing in which the socket is placed. The socket being thus adjusted to work in its casing in the same manner as a screw in a nut, it is clear that, by turning the handle O, with which it is connected, any desired degree of opening may be given to the valve.

The other end of the steam-pipe is divided into two branches J, J, most distinctly seen in fig. 5. These branch-pipes open into the two valve-boxes V, V, to the covers of which they are securely bolted by flanches formed for that purpose upon their ends. In each of the valve-boxes V, V, there is a sliding-valve *x* (fig. 8), which is just sufficiently long to cover the two passages opening into the cylinder. These valves are so connected with the engine as to move at the same time with it, and to open and shut alternately the communication between each end of the cylinders and their respective valve-boxes.

From this arrangement it will readily be perceived, that steam being generated in abundance in the boiler, and unable to escape from it, if the regulating valve *v* be opened by the handle O, the steam will pass into the steam-pipe S S, by the receive branch S′, and passing through the branches J, J, will enter the valve-boxes V, V, and thence pass into the steam-cylinders Y, Y, impelling the pistons alternately from one extremity of the cylinders to the other. Thus, putting arrows to indicate the direction of circulation followed by the steam from its entrance into the steam-pipe by the branch S′ till it arrives at the valve-box, and

confining our attention to its action in one cylinder, it is in the first place obvious, that the slide being in the position depicted in fig. 8, the passage 1 is open to the steam, and consequently the piston is impelled in the direction of the arrow. On the following instant the slide is brought by the motion of the engine into the dotted position, leaving the passage 2 open to the cylinder, and the piston is impelled in the opposite direction. It will also be observed, that the slide and steam-passages are so adjusted to each other, that when one passage is open to receive steam from the valve-box, the other communicates with the hollow interior of the slide. From this the steam escapes from the cylinder through the eduction port *e* into the pipe I, and thence through the funnel into the atmosphere.

But the disposal of the waste steam is not the only object attained by thus allowing it to escape through the pipe I into the atmosphere. A large aperture, opening directly into the atmosphere, would serve this purpose even more effectually; but it can easily be conceived, that as the jet of steam rushes with force from the mouth of the pipe I, it rapidly expels the gases which occupy the chimney, leaving behind it a partial vacuum, which is immediately filled by an equal volume of air rushing through the fire-grate. By this means the fire is excited to great intensity, the jets of steam thrown in rapid succession into the funnel, producing precisely the same effect as if the fire were continually urged by bellows. Indeed, such is the importance of this artificial current created in the fire-box, that, were the pipe I (called, from the office it performs, the *blast-pipe*) removed, the engine could not be supplied with steam, either in sufficient quantity, or of sufficient elastic force, and would therefore become almost useless as a locomotive.

In connexion with the foregoing explanation of the manner in which the steam is made to produce its effect in the cylinders, it is to be observed that the face of the slide-valve *x* is kept constantly in contact with its seat by the pressure of the steam upon its external surface. The pressure of the steam upon its internal surface in like manner tends to force it out of contact; but this surface being less than the external surface, it is kept in contact by a force proportioned to the difference of area of these surfaces, and the difference of the interior and exterior steam-pressure. The object of introducing the steam into the steam-pipe by the branch S′, which rises into the dome D, called the steam-dome, and which is purposely elevated, is to prevent the jolting of the engine, and the ebullition in the boiler throwing the water into the pipe, through which it would pass to the cylinders, and if in quantity would be a source of much annoyance. The cylinders themselves are placed horizontally, and parallel with each other in the lower part of the smoke-box, where the passage of the flames and the heated gases protect them against the condensing effect of the cold air, and keep them at a proper temperature. They are fastened to the tube-plate *p p*, by bolts and nuts, and to the framing of the engine and each other by the wrought iron straps *u u*.

The next point of inquiry is the manner in which the alternate rectilineal motion of the pistons is transferred to the wheels of the engine, producing in them continuous rotatory motion. This effect is clearly represented in the section, fig. 3, and in the plan, fig. 4, which supposes the tubular compartment of the boiler to be removed, in order to show the machinery beneath it; and, for the sake of distinctness, shows different portions of the mechanism in the two equal longitudinal divisions of the drawing. Here it will be observed that the piston-rods P are continued by the connecting-rods Q to the cranks R of the crank-axle. Fixing our attention upon one of these connexions, it is plain that, when the piston is forced alternately backwards and forwards, it must cause the crank to turn, and at the same time the axle and the wheel W, which is *fixed* upon it. But, as in the motion of a crank there are two points in which the alternating force acting upon it has no greater tendency to move it in one direction than in another—which is the case when the radius of the crank is in the direction of the moving force, and consequently twice during every revolution—the two cranks corresponding to the two pistons are placed at right angles to each other, so that one of the two has always its full effect whenever the other ceases to act. The power of the engine is thus uniformly transmitted to the crank-axle, which being once set in motion, the wheels are made to revolve with it; and consequently the whole machine is carried forward in a direction, and with a velocity corresponding to the motion communicated to the wheels from the pistons; the adhesion of the wheels to the rails which support them, causing them to advance, instead of slipping round.

As the axis of the steam cylinders, and consequently of the piston-rods P, are in a line with the centre of the crank-axle, it is obvious that some means are requisite to prevent any deflection of the piston-rods, at the same time that the connecting-rods are continually changing their lines of direction, in obedience to the revolution of the cranks upon which they are respectively placed. This condition is fulfilled in the following way:—The end of the piston-rod is fitted, by a cotter and gib, into a wrought-iron socket, which has two projecting arms at its end, parallel to each other. These arms have a semicircular notch at the end, to receive a turned iron pin of an inch and a-half in diameter. This is called the piston-rod cross-head. It is attached to the arms of the piston-rod socket by iron straps (*i i*, fig. 4), fitted on to both by a pair of keys and gibs. The ends of the cross-head are inserted into two steel guide-blocks *f*, (fig. 9), which are made with flanges to receive the guide-bars *m, m*. The guide-blocks and bars are ground together, and accurately fitted, so that the blocks may slide steadily and easily between the bars. One end of the bars is firmly attached to the flange *g*, cast upon the cylinder cover; and the other to a strong cross-framing *h h*, (most distinctly shown in fig. 6), secured to the side framing of the engine. The connecting-rods Q are fixed to the cross-heads of their respective piston-rods by strong iron straps *e′*, (fig. 4). To allow of this, the end L, fig. 3, is enlarged, and made square and flat; so that, being received between the parallel ends of the strap *e′*, the two are connected securely together by a key and gib. Upon the middle of the piston-rod cross-head a ball is turned, which is received in a set of brasses accurately fitted to it, and placed between the end of the connecting-rod and the strap *e′*, thereby completing the connexion in such a way as to allow of the required flexibility, at the same time that the uniform parallelism of the piston-rod is fully provided for and secured.

The construction of the other end of the connecting-rod, and the manner of attaching it to the crank, are much the same as described. The end L′ is enlarged and squared off, so as to pass between the parallel ends of the wrought iron strap *n*, which passes over the brasses fitted upon the crank-pin, and is fixed upon the end of the connecting-rod by a key and gib *l l*. The key terminates at the bottom in a screw which passes through the prolonged end of the gib, and is held fast by nuts bearing against the end of the gib when the key is driven into its place.

The manner in which the rectilineal motion of the pistons is converted into circular motion of the wheels is thus plain; but it remains yet to explain the means by which the alternate motion of the cylinder slide-valves, upon which the motion of the pistons depends, is obtained from the working of the engine. The mechanism by which this effect is produced is partially represented in fig. 3, and still more distinctly in fig. 7. In these drawings, and also in the plan fig. 4, are represented two cast-iron pulleys M and N fastened eccentrically upon the crank-axle. Now, the point O being the centre of the pulley M, it is clear that the axle in turning, the pulley being fixed upon it, will make that point describe a circle about its own axis; and in that motion the point O being successively to the right and left of the centre of the axle, the eccentric must of necessity alternately push and draw the rod M′, this rod being attached to a brass-collar, in which the eccentric pulley-block freely revolves. But the eccentric-rod M′ being connected with the valve-rod *r*, by means of the equal lever *q′*, whose fixed point is at the middle of its length, it is clear that when the centre O of the eccentric is carried by the revolution of the axle, from right to left of the centre of motion, the valve-rod must, in obedience to it, advance an equal distance from left to right, and *vice versâ*. Now, observing that when the steam impels the pistons from one end of the cylinders to the other, causing the crank-axle to perform half a revolution round its own axis, and the centre O of the eccentric to describe half a circumference about the same, the eccentric-rod M′ acting upon the valve-rod *r* in the manner described, must cause it to pass from one of its extreme positions to the other, that is, from one end of its stroke to the other. This being the case, the effect of the operation is, that the slides now admit steam on the opposite sides of the pistons, causing the crank-axle to perform its next half revolution, whereby the slides are again brought back to their original position to admit steam for the next stroke of the pistons.

From this explanation it will be seen that the action of the eccentric pulley is precisely the same as that of a common crank; but in this case, the object being to convert the circular motion of the axle into an alternate motion, to be applied to the slide with which it is in connexion, the principle of action is exactly the inverse to that which changes the alternate motion of the piston into a circular motion applied to the axle of the engine.

In our drawings two eccentric pulleys are shown, and these are both appropriated to the working of the same valve-rod. The rod M′, being in connexion with the lever Q′, works the valve when the engine is moving forward; and the rod N′, which is attached to the eccentric N in the same manner that the rod M′ is attached to the eccentric M, works the valve when the machine is moving in the opposite direction. The two eccentrics for working the slide-valve of the other cylinder are not shown. They are fixed upon the axle in the same relative position, but at right angles to those shown. The radii of each pair of eccentrics are thus at right angles to the radius of the crank to which their action refers; so that, when the crank is on the centre, and the piston consequently at the end of the cylinder, and about to change its direction, the eccentric is in full action, communicating to the valve its most rapid motion at the moment that it is required to reverse the steam passages. This disposition is, therefore, of the utmost importance to the efficient working of the engine. It not only causes the steam ports to be entirely open during the greater part of the time employed in the performance of the stroke of the piston, thereby allowing time for ingress and egress of the steam; but it also changes the communications of the steam as suddenly as possible, and at the most favourable instant—that is, when the piston is at the end of its stroke, and ready to alter the direction of its motion.

It has already been intimated that the eccentric N, with its rod N′, is brought into action when the engine is required to go backwards. To understand how this is effected, we must refer again to fig. 7; and, in the first place, observe that the long hand-lever X must be supposed fixed to the side of the fire-box, within reach of the engine-driver when standing upon the foot-plate P′ P′. This lever is connected by the rod V′ with another lever, X′, fast upon the shaft that carries the lever *y*, from which the gab of the eccentric-rod M′ is suspended by a link. In this it is plain that if the lever X be drawn back to the dotted position P′, the lever X′ will, in like manner, be drawn back to the dotted position *p*′; but the lever *y*, being fast upon the same shaft with X′, will be elevated through a corresponding arc, and, carrying with it the rod M′, will disengage it from the lever Q′. The lever *z* will, by the same change of position of X, be depressed precisely as far as *y* is elevated, by means of a crank, which works into a slot in the lever *z*. Both of the levers *y* and *z* being thus brought to a horizontal position, and being connected respectively by their links with the eccentric-rods M′ and N′, these last will likewise be brought to a horizontal position, and parallel with their respective levers. If now the lever X be drawn back to the dotted position R′, the lever X′ will follow to the position *r*′, by which the lever *y* will be raised to the position of the lever *z*, and the lever *z* will be lowered to the position of the lever *y*—that is, until the gab of the backward eccentric-rod N′ rests upon the stud of the lever Q′, as that of the eccentric-rod M′ is shown to do in the sketch.

From this it is clear, that the engine, in as far as this apparatus is concerned, may be made to travel with equal facility in either direction—each pair of eccentrics causing the steam to act inversely upon the pistons, which, transmitting their motion to the wheels through the crank-axle, communicates to them a corresponding rotatory motion in the direction desired. In some other engines only two eccentrics are employed to produce both the progressive motion of the engine, and the retrograde. This implies a modified form of the apparatus described; but the principle is the same, and need not be further referred to in the mean time.

During the working of the engine, it is obvious that the boiler will require to be constantly replenished with water to supply the place of that which is continually being converted into steam, and ejected through the blast-pipe into the atmosphere. This is effected by the two forcing pumps Z, placed under the body of the machine in connexion with the piston-rods by which they are worked. These pumps are formed of cast brass, and are firmly fastened to the outside framing, as shown in the plan fig. 4, and transverse section fig. 6. The length of the stroke of the pumps is equal to the *travel* of the pistons, their rams being directly attached (by wrought-iron clutches) to the piston-rod cross-heads—which are extended for that purpose beyond their outside guide-bars *m*, as seen at *o*. By the motion of the rams outwards, in obedience to the motion of the pistons in that direction, the water is drawn from the water-chest of the tender into the pump-barrels, whence it is forced by the return-stroke into the boiler.

These pumps are always in action, but they can only force water into the boiler, or rather, they can only draw it from the tender, when the cock of the suction-pipe *c c* is open. This cock is under the control of the driver, who opens and shuts it according as he finds occasion.

In order to know when this becomes necessary, a water-gauge *w*, (seen in figs. 1 and 5), is attached within view, to show at all times the height of the water in the boiler. This gauge is a glass tube, incased at both ends in two brass ferrules, which communicate with the interior of the boiler, and through which the water passes into the tube, and takes the same level as in the boiler. As the glass tube, however, is liable to damage, cocks are placed in the top and bottom sockets, which open into the boiler, and which, in case of the tube breaking during a run of the engine, can be shut. But as it would be unsafe to be without the means of ascertaining the quantity of the water in the boiler while working, three small cocks are attached to the side of the boiler at different heights: one of these is placed a little below the proper water-level, and ought, on being opened, to eject water; another at that level, and the third a little above it, and which, therefore, on being opened, ought to eject steam; so that by opening the three in succession, the level of the water in the interior can be ascertained with tolerable exactness.

Although it be necessary to the efficient working of the engine that the boiler be capable of generating steam of high elastic force, it is yet essential to safety that the steam pressure be within certain limits. In order to ensure this, the boiler is provided with two safety valves. One of these is placed on the top of the steam dome D. It is weighted by a lever *w*′, and spring-balance *z*′, on the face of which is a graduated scale and index. One end of the balance is attached to the fire-box; the other is attached to a screw-rod which passes through the end of the lever *w*′, over which is a large nut that can be worked by hand, so as to give the spring of the balance the desired degree of intensity. The balance is so placed that the engine-driver, standing on the foot plate P′ P′, may see at any time the pressure of the steam on the square inch of the safety-valve, and consequently on the whole interior surface of the boiler. The end of the lever is also so placed that he may reach the nut, and screw or unscrew it as circumstances may require.

But as the engine-driver might be tempted to overload this valve in order to obtain from the engine a greater effect even at the risk of damaging it, the second valve F, is loaded by a spiral spring and screw at such a pressure as may be considered safe, yet higher than the engine is expected under ordinary circumstances to require; it is then covered over with a brass dome, as seen in the elevation fig. 1, and section fig. 3, to prevent the driver or any other person from overloading it. By this means the elasticity of the steam cannot exceed a known point; as in attaining the pressure to which the valve is weighted, it would escape into the atmosphere without producing any useful effect.

As the weight of the engine rests entirely upon the wheels, it may be expected to suffer from jolting in passing over the irregularities of the rails. To obviate this as far as possible, the springs U U are interposed, as represented in the elevation fig. 1, and separately on a larger scale in fig. 10. These rest upon the axle-boxes *a a*, by means of vertical pins which pass through holes in the frame of the engine. One end of the pin resting thus against the back of the spring, and the other on the upper side of the axle-box, the whole weight of the engine is supported by the wheels, but only through the intermediate action of the springs. As the springs bend beneath the weight of the engine, the axle-boxes slide up and down between the axle guides *a*′, *a*′. The upper part of these boxes are scooped out to form small reservoirs for oil which is constantly supplied to the rubbing surfaces by a tube and syphon-wick. The other rubbing parts of the engine are lubricated in the same manner.

To deaden the shocks which may be given or received by the engine, it is provided with buffers or pads B′, B′. These are attached to the beam B, B, which is firmly bolted to the ends of the outside

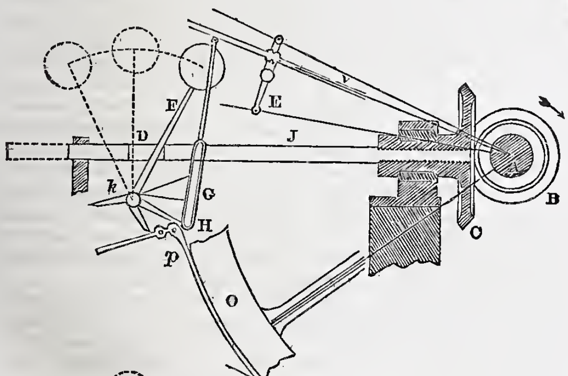
frames A A, which extend the whole length of the engine and round the fire-hox. To the cross-piece at this end, the platform, P′ P′, is securely attached. This is the stand for the engine-driver and his assistant, and is enclosed by rails to lessen the chances of accident.

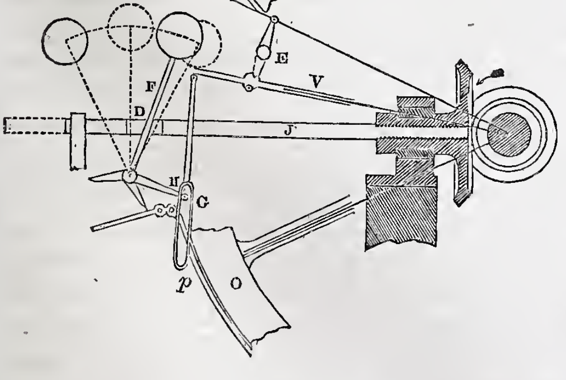
As a precaution against accident, a *whistle*, W′, is attached to the top of the fire-hox, and communicates with the steam inside the boiler by a short pipe, into which a stop-cock is placed. The handle of the cock is within reach of the driver. Over the pipe is placed a sort of inverted cup, against the edges of which, on turning the cock, the steam forcibly impinges, causing a shrill and not very agreeable sound, like that of a boatman's call. The whistle, when in action, is heard at considerable distance, and is the means provided to the driver to announce, at a distance, the approach of the engine and its train.

In this explanatory description we have purposely avoided, as far as possible, all technical details, in order to exhibit more connectedly the general disposition and uses of the several parts in the construction of engine represented by our drawings. This differs, as already observed, in several particulars from engines constructed hy other engineers; but the general principles are the same, and the peculiarities will readily be understood from subsequent examples. In our next chapter we will take up the subject where we have here left it, but in a more technical form, and more in detail.

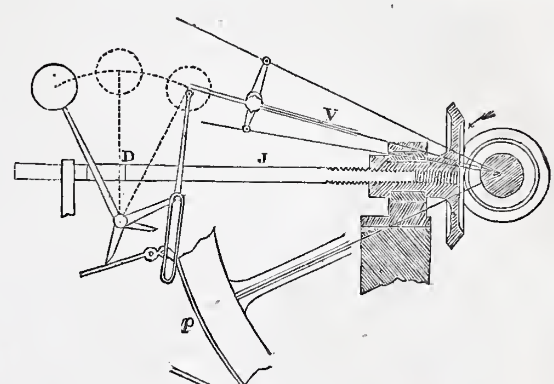
## SELF-ACTING STOPPER FOR WINDING ENGINES.

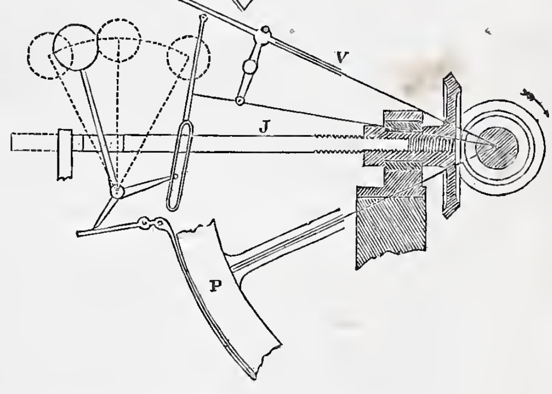
The apparatus depicted in the following drawings is to be attached to the gearing of the engine, so that, independently of the engine-man, the machinery would stop when the bucket or tuh had reached its proper height. It was designed in order to obviate the numerous accidents which occur in consequence of winding-engines at coal pits being left in charge of careless engine-men.




These drawings show the apparatus in different positions, and may be shortly described thus:—A is the fly-wheel shaft of engine, on which is fixed a bevelled pinion B, which works the wheel C; into the eye of this wheel a screwed rod J moves, having an oblong hole D at the opposite end; V is the eccentric rod, E is the double hand-gear crank, O is part of the fly-wheel, *p* is a friction-strap, F is a lever with a heavy hall of metal on the upper end, G is a link connected to the eccentric rod. In this link a pin, fixed in a lever H, is made to move freely, so that when the edge of the oblong hole D, comes in contact with the ball-lever F, it will throw it either way, according to the direction in which the engine and screwed rod J moves; when the lever F falls, it will tighten the friction-strap on fly-wheel, and throw the eccentric rod out of gear, by the pin in the lever H acting on the top, or under side of link G. The reason why the link is long, is to allow the crank and pin H to travel (by the screwed rod in wheel), without moving the eccentric rod out of gear, till it arrives at either top or bottom of link, which is the proper time that the engine should be stopped, the tubs being then at the proper height. A handle is attached to the shaft K, for the purpose of allowing the engine-man to take the strain off the friction-strap to let the engine get under way.




This apparatus was submitted to the Royal Scottish Society of Arts, by the inventor, Mr. John Maxton, F.R.S.S.A., engineer, and was considered worthy of the Society's silver medal.

## THICKNESS OF CAST-IRON PIPES.

The thickness of metal required for absolute strength in cast-iron pipes of given diameter, and intended to resist determinate internal pressure, is reckoned $0{\cdot}0002\,p\,d$ inch; where $p$ is the pressure in pounds avoirdupois, and $d$ the internal diameter in inches. If, therefore, $p$ be 40 lbs., and $d$ be 14 inches, then the thickness of metal for the required pressure will be $(0{\cdot}0002 \times 40 \times 14)$ inch $= 0{\cdot}112$ inch. Another formula is $0{\cdot}0001\,h\,d$ inch; where $h$ is the height of water pressure in feet, and $d$ the diameter of the pipe in inches; so that the head of water answering to 40 lbs. being 88 feet, this formula gives $(0{\cdot}0001 \times 88 \times 14)$ inch $= 0{\cdot}1232$ inch. Experiments upon this subject are still wanting.

## MACHINE FOR SLOTTING, BORING, TURNING, AND VERTICAL PLANING.

By M. Cavé, Engineer, Paris.

This machine is designed principally for heavy work, such as the connecting-rods and cranks of steam-engines, which it finishes both on their circular and plane surfaces.

Figs. 1 and 2, are elevations of the machine, and figs. 3 and 4, are the corresponding vertical sections. The same letters denote the same parts in all the figures.

The frame of the machine consists of four cast-iron fluted pilasters, marked A, and of a series of horizontal transverse pieces, marked B, e, D, E, fixed to the main frame. This frame is surmounted by another frame-work F, consisting of four curved branches, terminating in a rectangular cornice.

At the middle of the frame-pieces e and D, brass bushes *a a*, are fitted to support the spindle. The under frame-piece E, serves as a fixed platform to carry the sliding tables upon which the work is fixed.

*Mechanism for slotting and vertical planing.*—The spindle G, is one of the principal parts of the machine. It is of cast-iron, hollow and cylindrical throughout; it moves in the bushes *a a*, and as it alternately ascends and descends, its motion is perfectly rectilineal and vertical as respects the axis of the machine. It is bored at its lower end to receive the cylindrical piece H, which carries the tool *c*. This tool may be changed to suit the work to be done. It is fitted into a vertical slot, and fixed by a wedge *d*, which can be tightened at pleasure. The tool-stock H, is fixed to the spindle G by a key which is driven out when the kind of tool is to be changed.

*Vertical motion of the spindle.*—On the extremity of the horizontal shaft I, which runs the whole length of the machine, is a pulley J, and also two spur pinions K, which work into the spur wheels L, upon the shafts M; which run in bearings *e*, upon the upper frame-piece B. Two cast-iron circular discs N, are fitted upon the extremities of these shafts, one on each side of the spindle G; and two wrought iron connecting rods O O, are attached to the discs by the pins *f f*. The discs thus become in revolving, two variable cranks, the lengths of which depend upon the positions of the pins *f f*. The connecting rods unite the cranks to a horizontal transverse piece P, communicating to it a vertical motion led by the bushes *g g;* which slide in the cast-iron guides Q Q, bolted upon the frame of the machine. In the centre of the transverse piece P, a screwed rod is fitted. This is employed chiefly in the operations of turning and boring; but in slotting it simply unites the cross-head P with the spindle G. By this means the motion of the pulley J is converted into a rectilineal motion which is transmitted to the main spindle.

*Mode of regulating the traverse and position of the main spindle.*—In altering the position of the pins *f f*, upon the discs, to effect a change in the length of stroke, their velocity of rotation is at the same time changed, and therefore also that of the driving pulley. To effect this, the driving shaft has several pulleys of different diameters upon it; and by means of these, the required motion is attained. It is also necessary to adapt the motion of the tool to the work to be done; this is effected by means of the screw R. To work this screw, a horizontal spur-wheel T is fixed upon it, above the transverse piece P; this wheel is always in gear with the long pinion U. Upon the lower end of this pinion a small wheel is placed, over which passes an endless chain *h;* this chain passes over another small wheel on the top of the rod *i*, which descends to the hand of the workman, and terminates in a convenient handle *j*, by which it can be readily turned either to the right or left according as the tool is to be raised or lowered.

*Carriage.*—The form of carriage adopted for supporting the piece to be slotted or planed, and to communicate to it the required motion, whether rectilineal, circular, or vertical, consists first of a circular platform V, of cast-iron, properly grooved, to receive the bolts employed in binding down the piece operated upon. The periphery of this platform is cut into helicoid teeth, of a proper pitch and form to receive the thread of an endless screw *l*. Another part of the carriage consists of a large and strong rectangular plate X. Upon this is placed the working platform, the socket of which passes through its centre. This plate is well finished upon both surfaces; its motion is in a direction parallel to the greatest width of the machine, being fitted to move between the parallel guides *m m*, (fig. 4.) A screw *n* is placed within it, parallel to these guides. Another part of the carriage is the large plate or platform Y. This, in its turn, carries the plate X, and rests upon the frame E. The motion of this platform is in a direction perpendicular to that of the plate above it, and is guided by two slides *o o*, fixed upon the frame E. It has likewise an internal screw *p*, by which its motion is adjusted.

*Motion of the different parts of the carriage.*—When a circular motion is required, one of the shafts M is made to turn the endless screw *l*, by a mechanism which is not represented in the figures: this causes the platform V upon which the work is fixed, to revolve in its own plane. If, on the contrary, a rectilineal motion be wanted in either of two directions, the mechanism is applied to the corresponding one of the feed screws *n, p*.

These movements may be effected by hand, by means of the lever H′, (seen in fig. 1), which can readily be put upon the projecting end of any of the feed-screws, *l, n, p*. This lever is provided with a click *f′*, and toothed ratchet *g′*, by which it turns the screws through a certain space at each successive throw.

*Mechanism for boring.*—We have seen that for slotting and planing the spindle O is moved up and down rectilineally; but for boring it must turn on its own axis. For this purpose, a horizontal wheel Z is fitted upon it, and gears into a long hollow pinion A′, which is mounted upon a vertical rod; this axle is supported at its lower end, upon a bracket attached to the frame, and carries on its upper end a bevel wheel B′; this last gears with another wheel e′, fitted upon the shaft D′ which receives its motion from a three-speed pulley S. When this shaft is required to give motion to the spindle, the pinion e′ is engaged with the wheel B′ by means of a lever *q*. This lever, which is keyed upon the horizontal axle *r*, answers the purpose of a fork, for engaging and disengaging the pinion e′. At the end of the axle *r*, and outside of one of the bearings *s*, which support it, there is a vertical handle attached, which is caught in one of the recesses of the notch-piece *u*. It is now clear that, in passing the handle from right to left, so as to engage it in the first tooth of the piece *u*, the rod *t*, by the movement of the axis upon which it is mounted, will also pass from right to left, and bring the pinion e′ into gear with the wheel B′. This change may be effected while the shaft D′ is revolving.

When the machine is to be employed in boring, the piece to be bored is made fast upon the platform V; and the machine being put in motion, the spindle descends with a velocity proportional to its rotative motion. This is effected by a very ingenious mechanism. On the top of the spindle a cast-iron socket *v* is fitted and retained in its place by two pins passing on each side of the screw R. This socket has on its upper side a toothed circle in which the spur-wheel *x* works; this is fixed upon a vertical axle, carrying a pinion, which likewise gears with another wheel *z*, mounted loose upon an axle similar to the preceding. This last is cast of a piece with the pinion *y*, which gears with the large wheel E′, in the centre of which is a large female screw, having its lower end confined between the top of the axle and the interior flange, as it may be termed, of the socket *v*.

The bearings of the intermediate wheels are fitted upon a bridle *a′* in two pieces round the socket *v;* but in order that they may not be carried along with it in its motion, this bridle carries an ear through a hole in which the rod F′ passes and guides the bridle.

From this arrangement it follows, that the spindle G sets in motion, by its rotation, the socket *v* and toothed circle; this last again moves the intermediate wheel *x*, and consequently the two other wheels, *z* and E′.

*Mode of adjusting the tool-spindle.*—The piece to be bored being in its place, it is necessary to determine the height to which the tool ought to be raised in order that the cutters should be immediately over the part to be bored. When the boring is finished, the spindle is raised to disengage the tool. To effect this we must bring the wheel O′, upon the bottom of the large pinion A′, into gear with the endless screw *b′*, of which the axle *c′* is furnished with a crank *d*, which may be worked by hand. The axis of this screw is carried at one end by the handle *t*, the middle of which is enlarged, and has a hole through it; and at the other extremity by the lever *e′*, which is itself suspended from the axle *r*. It follows from this, that when the pinion c′ is disengaged, by pushing the handle *q* to the right or left, the endless screw *b′* is at the same time engaged with the wheel G′: and also when the pinion c′ is engaged with the pinion B′, we disengage thereby the endless screw.

# MACHINE FOR SLOTTING, BORING, TURNING & VERTICAL-PLANING.

*By M Cavé Engineer. Paris.*

1 2 3 4 5

*Scale of English Feet*

Fig 1.

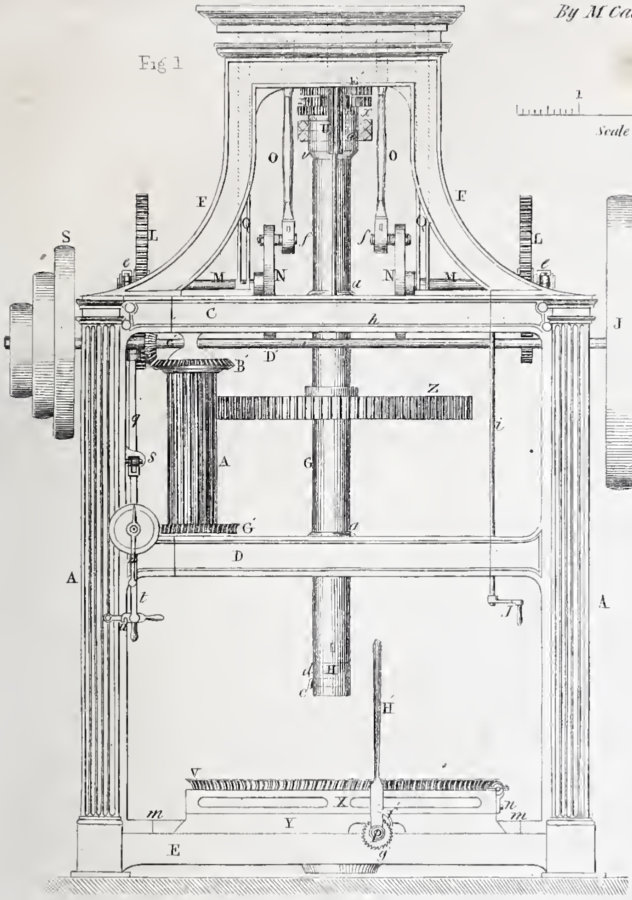


Fig 2.

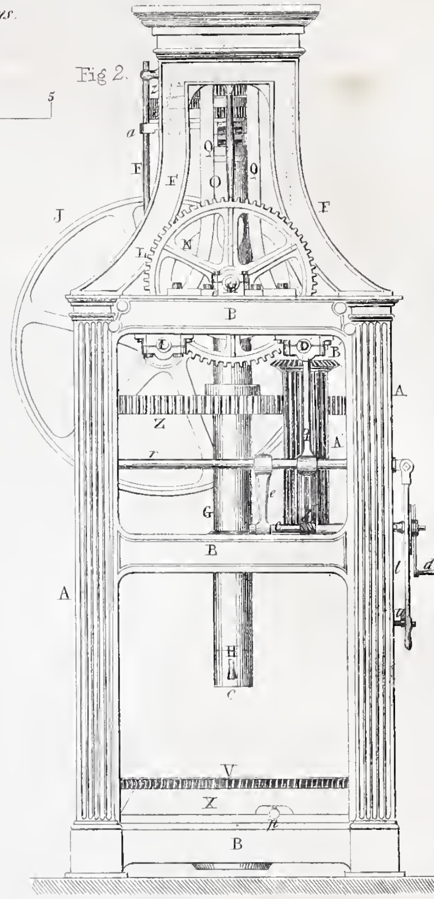


Fig 3.

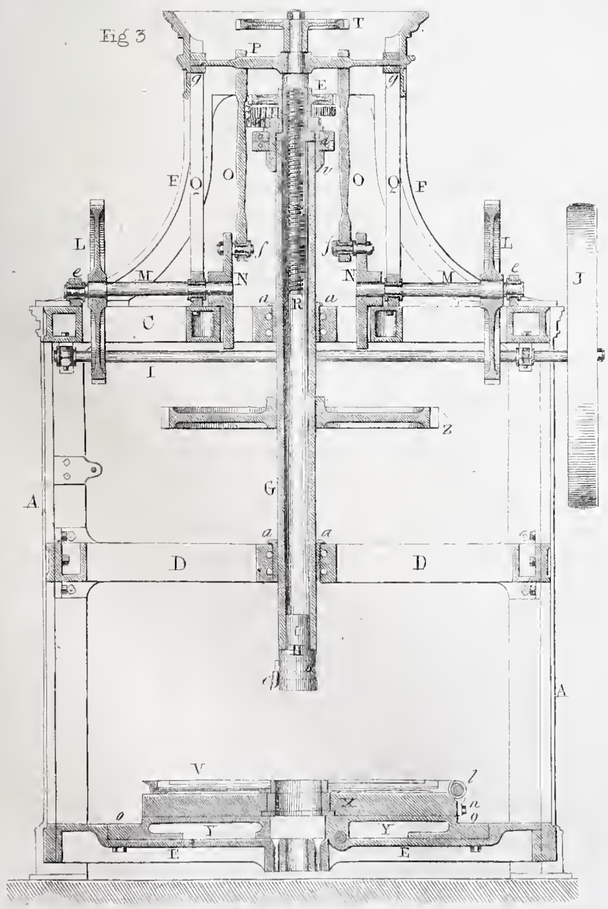
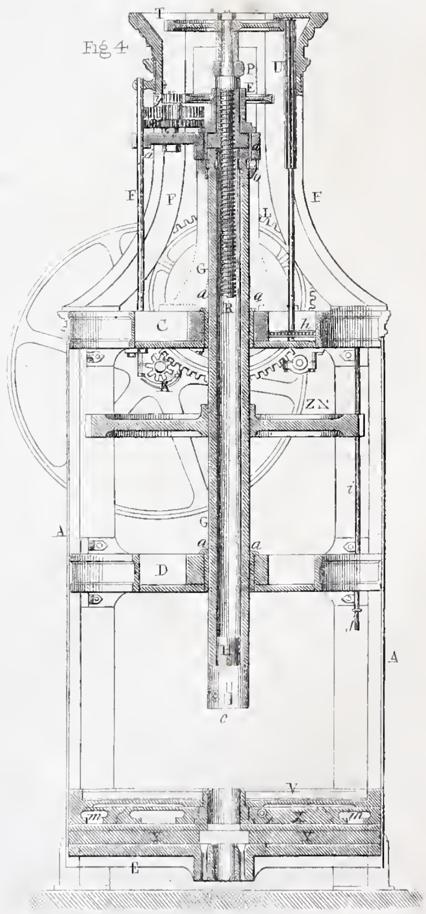


Fig 4.



# THEORY AND PRACTICE OF DYEING.

## CHAPTER II.

### TANNIN AND GALLIC ACID.

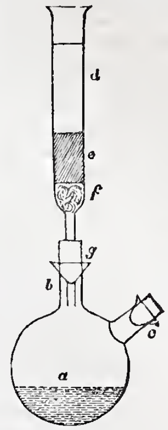
The green of leaves, and the colours of flowers, are common to all vegetables under the influence of light; but there are a number of colouring substances in vegetables which are peculiar to certain orders, and which exist as proximate elements sometimes in the leaves, in the woody part, in the juice, in the bark, in the seeds, and in the roots. Several of these have been made more subservient to our use in the art of dyeing, and will require to be noticed separately.

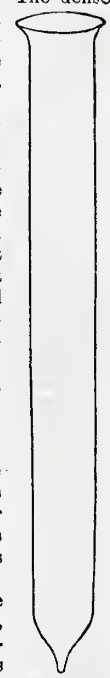
Many attempts have been made to transfer the colouring matter of flowers to cloth,* but without success. In general, they are so fugitive, as to change the moment they are brought into contact with the atmosphere, and those of them which can be extracted, have no affinity for the cloth. If a third substance be used to give this affinity, it destroys the original colour of the vegetable. This is the case with nearly all vegetable colouring matter; for, if we except indigo, there is scarcely another substance which is capable of imparting its own colour to cloth. Again, the colouring matter of flowers is very limited in its changing hues by artificial means. Acids change it to red, and alkalis to green, but these substances, though they thus act upon the colouring matter of vegetables, cannot serve as bonds of union between the colour and the cloth with which they do not themselves possess the property of combining. The substances which act the part of intermedia to the vegetable colouring matters used in dyeing, do not affect or combine with the colouring substances. This property of combining with mordants, no doubt depends upon the chemical composition of the colour, and the effects produced by these colours being in union with other substances which combine with the mordant upon the cloth. These substances are tannin and gallic acid, and so far as our observations extend, it is to the presence of one of these that most dyewoods owe their dyeing properties. At all events, the great variety of hues which they are capable of imparting to goods when combined with the oxides of the metals, are dependent upon these principles. We will, therefore, previous to noticing the different dyeing agents, such as indigo, logwood, Brazil wood, sumac, madder, catechu, &c., endeavour to explain the nature and properties of tannin and gallic acid.

Upon certain species of oak there grow excrescences, which originate in punctures, made by a peculiar insect, for the purpose of depositing her eggs. A kind of juice exudes from this puncture, and gradually forms round these ova hard round bodies, varying in size from one-fourth of an inch to a whole inch in diameter. These substances, from their resemblance to nuts, and from their bitter taste, are called gallnuts.† By the repeated experiments of many excellent chemists upon this substance, it is considered to contain two peculiar principles. One of these, a crystallizable substance, is obtained from a macerated solution of galls, after standing in the air for a long time. This, from its possessing many acid properties, is termed gallic acid. The other being that substance which combines with skins, during the process of tanning, changing them into leather, is termed tannin, or, from its having some acid properties, tannic acid.

From these two substances being always found associated together in one vegetable, it was thought probable that the one might give rise to the formation of the other. This supposition has been recently verified by M. Pelouze, an eminent French chemist, who, by the following exceedingly simple process, extracted tannin from galls in a state of purity.

To the vessel, represented by the annexed figure, is fitted, by means of a cork *g*, a funnel-shaped tube. The neck *c* is to be kept corked, air-tight, during the process. At the bottom of the tube is placed a little clean cotten, as shown at *f*. Above this cotton is placed a quantity of nut-galls in fine powder, as shown at *e*. Over this is poured a quantity of common sulphuric ether, sufficient to fill the rest of the tube as seen at *d*. A cork is then fitted tightly in the opening at the top of the tube, and the whole set aside. Next day two layers of liquor are found in the vessel *a*, one very light and liquid, occupying the upper part, the other having a light amber colour, and the appearance of a syrup, occupying the lower part. These liquids being poured into a tube of the shape annexed, stopping the bottom with the finger, after remaining at rest for a few minutes, the liquids again separate; the heavy liquid being then allowed to fall out into a capsule, and the light retained, this last may be distilled for the sake of recovering the ether. The dense liquid which is in the capsule is next to be washed two or three times with sulphuric ether, and afterwards dried in a stove, or by very gentle heat; the matter left has a spongy appearance, very brilliant and generally of a light yellow tint. This is tannin in a state of purity. By this process, from 35 to 40 per cent. can be extracted from nut galls.



M. Pelouze found that if a solution of tannin be kept closely corked from the atmosphere, no change takes place; but if left in contact with oxygen, the tannin undergoes a change, and gallic acid is formed. Hence he concludes that gallic acid does not exist except in very minute quantity in vegetables, and that the error of supposing that these two acids existed together in vegetables, arose from the method adopted to procure gallic acid, which was by allowing the macerated vegetable matter to stand in contact with the air, till the gallic acid crystallized from the solution, this being nothing more than a process for converting tannin into gallic acid by the absorption of oxygen.

This one discovery is of great importance to the dyer, as it points out the evil of allowing liquids which contain tannin, to stand exposed to the air for any length of time; for although gallic acid acts in a somewhat similar manner with metallic oxides as tannin acid, yet the gallates are much more fugitive than the tannates. For example, if we precipitate tannic acid and gallic acid by a persulphate of iron, they are both dark blue, bordering on black; excepting a slight change of shade, the tannate remains permanent; but if the gallate be allowed to stand a few hours, it is dissolved in the supernatant liquid, and becomes almost colourless; the sulphuric acid resumes its attraction for the iron, and crystallizes as a protosulphate (copperas) and the gallic acid is partly decomposed, and partly crystallized. These changes take place in a few minutes, if the liquor containing the precipitate be boiled. Now, if galls, or what is now more commonly used instead, sumac, be allowed to stand till after fermentation takes place, which is very soon, a great portion of the tannin is converted into gallic acid; and although the cloth dyed in sumac that is thus altered, should be, as some dyers affirm, equally dark, it will not be equally fast; but from personal experience, it is neither equally dark nor equally beautiful. It cannot be so dark, for gallic acid being much more insoluble than tannin, falls to the bottom whenever it is formed, and consequently leaves the supernatant liquid much weaker in its dyeing properties.

More recent discoveries have shown that tannin is convertible into gallic acid, by other and much more rapid means than being left to absorb oxygen; these are by the common processes of inducing fermentation. It is well known that fermentation is simply a derangement of the elements of certain complex compounds,

* The word cloth will be used indiscriminately, without reference to a particular fabric, the remarks being equally applicable to yarn, except where otherwise stated.

† The excrescences are produced by the *cynips* (gall-wasp), upon the tender shoots of the *quercus infectoria*, a species of oak which is common in Asia Minor. When the maggot is hatched, it eats its way out of the nidus. The best galls are those brought from Aleppo and Smyrna.

and the arrangement of these elements in different positions and proportions, giving rise to new and altogether different compounds of a more simple nature, that is, having a smaller number of elements. The primary compounds are formed under the unknown influence of the vital principle ; but whenever this principle is withdrawn, they seem but passively to retain their chemical conditions. The attraction of their elements seems too weak to enable them to resist any marked change of circumstances. Even a slight elevation of temperature is sufficient to overpower their affinities and induce change. As in the case of fermentation, if they are brought into contact with a body which is in the act of derangement, that body excites the same derangement in them, and the equilibrium being disturbed, the elements are left to arrange themselves according to their different attractions. If, for example, we dissolve a little sugar of grapes, which is composed of 12 carbon, 12 hydrogen, and 12 oxygen, in a little water, and raise the solution to a temperature of about 80° Fah.; and if to this we add a little yeast, which is a substance whose atoms are in the act of transposition ; the yeast does not combine chemically with the sugar, but it communicates to it by contact the action of transposition, and thereby deranges the arrangement which the atoms had assumed to form sugar; and the atomic elements being thus set at liberty, begin to arrange themselves differently : every three atoms of the hydrogen combine with two of the carbon, and one of the oxygen, forming four atoms of alcohol. The remaining eight atoms of oxygen unite with the remaining four of carbon in the relation of one to two, forming four atoms of carbonic acid gas. Thus the whole sugar is converted into two different substances, of which the yeast forms no part. It only acts the part of a bold revolutionizer, breaking up existing compositions, that new ones may be formed from their elements. Now tannin is found to undergo the same sort of change as the sugar, when brought into contact with certain substances ; and one of the new compounds formed from this transposition, is gallic acid. M. Antoine has indeed directly shown, that a very small quantity of nutgalls is capable of converting a large quantity of tannin into gallic acid. The following are some of the experiments which he made to ascertain under what influence this change is operated. "I used," he says, "nutgalls exhausted by ether as a ferment, and this I put in contact with the solution of tannin, which served as a liquor of comparison, or type liquor.

"On the 27th of August, 1840, I took 10 grs. of nutgalls exhausted by ether, 5 grs. of tannin, and 110 grs. of water ; the type liquor consisted of 110 grs. of water, and 5 grs. of tannin. I kept these liquors in flasks covered with paper, and perforated with holes, until the 21st of September; and as I then wished to ascertain the state of the liquors, I took one grain of each, and added an excess of sulphate of quinine, (a substance which precipitates tannin). I obtained no precipitate from that containing the nutgalls, the type liquor on the contrary gave an abundant precipitate. I did not expect so good a result. I multiplied my experiments, and as the following corroborate the preceding, it will be seen that a small quantity of nutgalls is capable of converting 15 grs. of tannin into gallic acid.

"On the 23d of September, I put into a wide-mouthed flask, 5 grs. of tannin, 5 of nutgalls exhausted by ether, and 100 grs. of distilled water, and I exposed it to the air until the 7th of November. Into a second flask to the same quantity of water and nutgalls, I added 8 grs. of tannin, and to a third, 15 grs. of tannin. On the 7th of November, I precipitated the tannin from 5 grs. of each of these liquors, and I obtained exactly the same weight of tannate of quinine from each. These experiments appeared to me very curious, inasmuch as even 15 grs. of tannin under the influence of 5 grs. of nutgalls exhausted by ether convert in a very short time as large a quantity of tannin. Finally, two other experiments made with 5 grs. of tannin, 128 grs. of water, and 5 grs. of nutgalls exhausted by ether, gave me after a contact of a month, $\frac{1}{25}$ gr. of tannate of quinine, whilst two other liquors prepared with the same proportions of water and tannin without any nutgalls, yielded $\frac{3}{10}$ gr. of that salt. These four liquors were prepared in the same day, and were exposed to the same influences."

The same author shows that galls have the same property as yeast in exciting fermentation in sugar for the production of alcohol, thereby proving, should additional proof be wanting, that galls contain within themselves a substance capable of producing fermentation and converting tannin into gallic acid. Now just in proportion as gallic acid is inferior to tannin in its dyeing properties, will be the extent of the evil of allowing liquors which contain tannin, and which depend upon it for their dyeing properties, to stand till fermentation begins. In some liquors this commences in the course of three or four days ; much however, depends upon the temperature.

But it may be asked, that although galls possess within them the property of a ferment ; does sumac, which has in many operations superseded the use of galls, possess the same property ? Whether sumac possesses the property of exciting fermentation in other substances, has not yet been determined ; but from a number of experiments upon the action of various substances upon tannin, it would seem either to induce or facilitate fermentation ; and further we venture to say that the tannin in sumac is more readily converted into gallic acid than the tannin of gall-nuts. If the liquor of galls be allowed to stand exposed to the air, it requires a considerable time before its tannin is converted into gallic acid, but there are a number of substances which, if put into it, causes the formation of gallic acid to proceed much more quickly. Amongst others, the tartaric and mallic acids possess this property in a high degree. Now, sumac according to some recent analyses contains a great quantity of mallic acid, which, were we allowed to reason from analogy in chemical science, places it under very favourable circumstances for fermentation. Indeed in certain seasons of the year, we have known it to ferment in 48 hours. Whether this fermentation was induced first by the tannin or the colouring matter which it contains—for sumac contains a distinct colouring matter—we cannot certainly in the mean time determine. A very short time however makes it lose its colouring property, but as we shall see in next paragraph, the addition of certain acids has the same effect upon this colouring matter, so that the losing of colour may be the effect of acids formed in the liquor, as well as the immediate effect of fermentation.

It may also be asked, seeing that the introduction of certain substances facilitates fermentation, is there no substance which can be introduced without destroying the dyeing properties of the substance which can prevent fermentation? The answer to this may be given in the language and experiments of the same author last quoted. "I made," he says, "some new experiments to ascertain the action of certain other agents on gallic fermentation. With the following liquids prepared in the same proportions (110 of water, and 20 of nutgalls both by weight), and to which I had added—to the first 20 drops of pyroligneous acid (red liquor), to the second 12 drops of sulphuric acid (vitriol), to the third 12 drops of nitric acid (aquafortis), to the fourth 12 drops of hydrochloric acid (spirit of salt). I obtained the following results, precipitating the tannin by sulphate of quinine.

| | |
|---|---|
| Type liquor gave | 0·60 centigramme |
| Pyroligneous acid | 0·35 centigramme |
| Sulphuric, . . | 0·59 centigramme |
| Nitric, . . . | 0·55 centigramme |
| Hydrochloric, . | 0·50 centigramme. |

"These results appeared to me to be very curious. Indeed where no agent could modify the progress of the phenomenon, the tannin was almost entirely converted into gallic acid, whilst in the liquors containing the above-mentioned bodies, the progress of fermentation is arrested, and very little gallic acid formed."

Although these results be very curious as regards certain chemical phenomena, the use of these acids as preventatives to fermentation is not advisable in a practical point of view, except when the sumac (for the remarks refer mutually to sumac and galls) is to be kept for a long time, and a possibility of using it for light shades ; for dark grounds, sumac with acid, does not give the same depth of shade, and as the goods require to be washed when the acid is used, previous to putting them into the iron, there is a waste of time without an equivalent advantage. But with light shades such as drabs, greys, &c., the addition of a little sulphuric acid to the sumac, makes a superior and uniform colour. When we say superior colour, we do not mean the yellow colouring matter which new boiled sumac possesses, for sulphuric acid destroys the colour. If pure white cloth be put through sumac at a temperature of 140°, light straw or lint colour is produced ; but if sulphuric acid be in amongst the sumac, the colour on the cloth is inappreciable. When the goods are washed from this, and put through a very weak solu-

tion of sulphate of iron (copperas) the colour which is produced is much sweeter, appearing fully and evenly combined with the fabric. When no acid is used, as is often the case, the colour often appears in grains upon the surface of the cloth. When sumac or galls are used, it is best for all purposes that they be fresh, and newly boiled or macerated.

The following table abridged from Brande's Manual of Chemistry, will give some idea of the action of some metallic salts upon a solution of galls or sumac.

| Names of Salts used. | Colour of Precipitates. |
|---|---|
| Protochloride of manganese, | dirty yellow. |
| Protosulphate of iron, (copperas) | purple tint. |
| Persulphate of iron, | black. |
| Chloride of zinc, (muriate of zinc) | dirty yellow. |
| Protochloride of tin, | straw colour. |
| Perchloride of tin, | fawn colour. |
| Sulphate of copper, (blue stone) | yellow brown. |
| Nitrate of copper, | grass green. |
| Nitrate of lead, | dingy yellow. |
| Tartrate of antimony and potash, | straw colour. |
| Tartrate of bismuth and potash, | copious yellow or orange. |
| Sulphate of uranium, | blue black. |
| Sulphate of nickel, | green. |
| Protonitrate of mercury, | yellow. |

In attempting to draw a practical inference from some of these results, we would for example conclude that persulphate of iron is much better adapted for dyeing blacks than protosulphate, as the former is mentioned as producing a deep black, while the latter gives only a purple tint. It is much to be regretted that in making out these tables, care is not taken to give the results in all their bearings. In the forms in which we meet them in chemical books, if they do not tend to lead practical men astray, they at least give a lower idea of the labours of scientific chemists. The results of the two salts mentioned are correct, looking at the results the instant the mixtures are made; but in the course of twenty minutes the black from the persulphate becomes a brownish slate, whereas the purple tint of the protosulphate changes during the same time to a deep black; and these changes continue till the former has become a light yellowish slate, and the latter a perfect ink black.

When trying the difference of effect produced by the persulphate and protosulphate of iron upon pure tannin and gallic acid, it may further be observed, that the changes produced with tannin are somewhat similar to those which occur in a solution of galls. With gallic acid the persulphate gives at first a black precipitate, not so dark as the tannate, but in a few minutes it changes to an olive, and continues changing till it becomes almost colourless. With the protosulphate, at first the colour is scarcely visible, but after an hour's exposure, it assumes a rich violet. From these facts, it may be concluded, that tannin is much superior to gallic acid as a dyeing agent for black; besides, it is much more insoluble.

Another thing which modifies the results of these experiments in their application to dyeing, is the quality of the water used. If the experiments be performed with distilled water, it will be found, on repeating them with common spring water, that one-half of the quantity of stuffs will give the same depth of colour; and, that the colours, in this instance, have more of a purple hue, and are much more permanent. This may be illustrated by a very simple experiment. Thus, take two glass jars of equal size, fill them half full with distilled water, and add an equal quantity of a solution of galls, or sumac; put into each an equal number of drops of a solution of protosulphate of iron (copperas); the change of colour is scarcely perceptible. But fill up one to the brim with spring water, and it almost instantly becomes a dark reddish black. Allow both jars to stand for an hour, the solution with the distilled water will have become a deep violet, while the other, notwithstanding the double quantity of water, is so dark that no light is transmitted; and it will require one-half more water to reduce it to the same shade as the other, but still retaining more of the reddish hue—which, by the way, makes it superior for black. It will also be found to be much more insoluble, and requiring a greater proportion of acid to decompose it. If soft, or filtered river water, be used instead of distilled water, the distinction is not so great, but still, the difference is equal to one-half. The best water which the writer has experienced for dyeing black, and other *saddened colours,** gave by qualitative analysis, carbonic acid, lime, silica, iron, sulphuric acid, and muriatic acid. The whole solid contents did not exceed one grain in a fluid ounce. These ingredients probably existed in the water as sulphate of lime, carbonate of lime, muriate of lime, and carbonate of iron. The iron was in very small proportion; the carbonic acid and lime greatest.† Now a dyer, learning his trade in a work where such a spring was used, could not fail to become a successful dyer of all saddened colours; but were he taken from this work to another where soft, filtered water was used, what would be the result? When he attempted to dye a black with the same quantity of dyestuff he formerly used, he would only produce a dark slate-colour; and if he wished to obtain a slate-colour, he would produce a grey. In this dilemma, the dyer adds stuff till he comes to the desired shade; but fancy-dyes, bolstered up with stuffs, are not so pretty; besides, the employer, in consequence of this extra stuff, must either submit to a loss, or discharge the dyer who, no doubt considering himself ill-used, talks loudly of his ability in dyeing such colours, and offers to prove that the fault is not in him but in the water. Were this wholly a supposed case, the writer would pause here and make an apology to his brethren for these remarks; but not being so, he will rather endeavour to show that the fault is the dyer's. Dyeing being an art wholly dependent upon chemistry for its development and successful practice, he who practises it without studying chemistry, is like a boy learning to repeat a number of choice sentences from an author, without knowing his letters. Had the dyer alluded to, known the principles of chemistry, so far as they are applicable to his trade, he would, on finding that the same quantity of stuffs did not yield the same results, have examined the water to discover where lay the difference, and in this particular case he would find, that instead of adding sumac, copperas, and logwood, extra to get a good black, a little chalk and hydrous gypsum (sulphate of lime,) added to the water, would so qualify it as to render it equally effective with that to which he had been accustomed.

The following is the process for dyeing black upon cotton goods:—The goods are allowed to steep in a decoction of sumac for twelve hours; they are then wrought through lime-water, which gives them a beautiful blueish-green colour, becoming very dark with a short time's exposure to the air. If allowed to stand for half-an-hour, the green colour passes off, and the goods assume a greenish-dun shade. When they are at the darkest shade of green, they are put through a solution of copperas; after working some time in this, and allowing them to stand exposed to the air, they become a black. But if dried from this, it is only a slate or dark-grey. They are again put through lime-water, which renders them brown, and then wrought through a decoction of logwood till the colour of the wood has nearly disappeared. A little copperas is added, which throws off the reddish hues of the wood, giving them a blue shade. This is termed *raising* the colour. The goods are washed from this in cold water, and dried in the shade. When a deep blue-black is wanted, the goods are dyed blue previous to steeping in the sumac.

There are a number of other vegetables besides galls and sumac, which contain tannin in great abundance, and which we shall notice in their proper place—particularly catechu. The various combinations of tannin with the metallic oxides, especially tin, will be noticed under the article *Mordants*.—We will next devote our attention to indigo and its uses.

## IRON FOUNDING.—Section II.

Having in the first paper on this peculiar art, given two detailed examples of the mode of moulding and casting light flat ware, illustrating generally, the manner of conducting the manufacture of these goods; the practice of hollow moulding falls now to be

* A technical name for colours that are darkened by sulphate of iron, which includes drabs, fawns, greys, slates, some kinds of browns, blacks, &c.

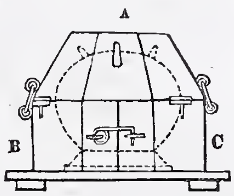
† We shall give the best methods of detecting the presence of these ingredients in water in the proper place.

described, as that branch of moulding naturally precedes in order of description, the heavier species of green sand moulding.

The distinct objects of hollow moulding are comparatively few in number, and small in dimension ; there are moulding boxes for them individually of corresponding shape, generally manageable by one person. Boxes in two, three, or four parts, are employed as the necessities of the case may require. We shall select for example, the moulding of an Irish pot, of which the annexed is a sketch.

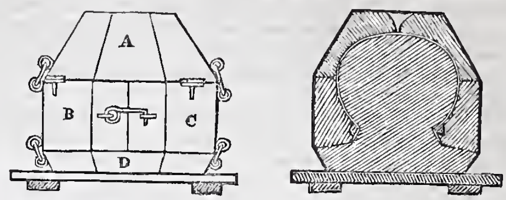
The body of it is nearly spherical, drawn in at the neck, and opening towards the brim. It has two ears at the neck, by which it is moved about when in use, and three feet on the bottom. The pattern is an exact model of the pot, being in two halves separating vertically. The patterns of the feet and ears are also loose on the body of the pattern, fitting to it by pins. To form an original pattern, the method usually adopted is that of moulding in loam, which will be understood afterwards when we come to describe this branch of the art. In the mean time, it is sufficient to state, that the rough cast pattern is chucked in the turning lathe, and turned within and without to the required form and thickness, in doing which, it is facilitated by boring four longitudinal rows of small holes through the pattern at equal distances round it, by which its thickness at any part may always be ascertained. Having been smoothed and polished, the pattern is taken from the chuck, and cut in two equal halves, in which holes are bored at the proper positions, for receiving the pins of the ears and feet. The pattern is moulded in a box, consisting of four parts, named the top, marked A in the ensuing figures, the two cheeks, B, C, and the bottom, D ; the division into parts is similar to that of the moulding box for axle bushes described in the preceding paper, supposing the middle part divided vertically in two, corresponding with the cheeks, B, C. The pattern being moulded in an inverted position, the top, A, is made to enclose the bottom of the pot, as far up as its largest diameter; the cheeks, B and C, enclose the remaining portion of the pot, and the bottom, D, serves to close up the mouth of it.

The two cheeks are first of all laid down on a level board and linked together ; the pattern is then laid down on its brim within the cheeks, being raised off the board by a slip of wood, of which the thickness is adapted to bring the largest diameter of the pot to the level of the upper edges of the cheeks. The patterns of the ears are attached, and sand is rammed in round the pattern flush with the cheeks, making the parting surface on the centre of the pot. The surface having been sprinkled with parting sand, the top, A, is put on, led into its place by guide pins, and fastened to the cheeks. Sand is again rammed in to the level of the mouth of the box, the patterns of the feet and the gate pin being set in their places in the course of the ramming of the sand. The annexed figure shows the position of things as now described.




The whole is next inverted, and the board and slip of wood removed. The surface of the sand round the brim of the pattern is smoothly sloped off to the edge of the box, forming the parting surface, and the bottom, D, is fixed on. It is also filled with sand. The body or core of sand filling the interior of the pattern is pierced in several places with a pricker sent down to the pattern, forming thereby channels of escape for the air expelled by the metal introduced. The whole is finally reinverted, D lying undermost, and placed on a flat board with a hole in it to allow the escape of the air. The sand outside the pattern is sometimes pricked, though this is but of little importance.

The part A is now separated and lifted off, carrying the feet and the pin with it. The cheeks, B, C, are next separated horizontally, taking the ears with them ; and the half patterns are withdrawn from the core. The external and internal moulds, thus exposed, are sleeked up with appropriate tools, and blackening is dusted on them, and also sleeked up. The patterns of the feet and ears, and the gate pin are drawn out, the boxes, B, C, are replaced exactly as before, and the box A, above them, the whole being again bound together. The mouth of the gate is next formed and smoothed. The space occupied by the pattern is now vacant for the metal. This is an external view and section of the box and moulding.

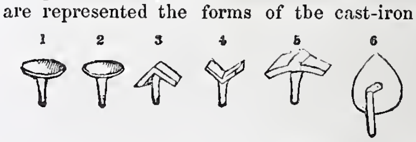



In the section are shown the parting surfaces, and the slope of the under one.

All dished utensils are cast with their mouths downwards, and in some cases the area of the mouth is so small compared with the largest diameter, as to render it necessary to bind down the core in the mouldings. For it is very evident that the iron lying so far in below the core, it tends by its upward pressure to lift the core off from its base. Such a result would of course spoil the casting. This binding is requisite in kettle mouldings in particular. It is simply effected by burying an iron rod in the core, having on it a cross at the end to give it a hold of the sand, the outer end being locked to a transverse piece which bears on the edges of the box.

The metal requires to be at a high temperature for hollow moulding ; for so quickly does it cool, that the brim of a moderately sized pot *sets* even before the mould is filled. While yet red-hot, the casting is taken out of the sand, and the gate piece knocked off. This must be done at a certain stage of the cooling, as when too soon done, the gate does not break clearly off ; and when delayed too long, it often carries out a piece of the bottom of the pot with it. With a view so far to provide against this, the pot is made considerably thicker at the centre of the bottom. Flat gates are formed for flat bottomed ware—frying pans for example. They are wide at the mouth to receive the iron the better, but taper like a wedge, towards the moulding, so as to be easily separated from the casting. By being of considerable extent, flat gates conduct the metal more speedily to the different parts of the mould.

Here are represented the forms of the cast-iron sleekers,




employed in the operations of hollow moulding. Nos. 1 and 2 show the convex and concave sleekers for corresponding surfaces. Nos. 3 and 4 are tools with double plane surfaces, at certain angles with each other. Of these there is a variety, having their planes at different angles to suit the various salient and retreating angles that occur in mouldings. No. 5 is a sleeker for the impressions of beads ; and No. 6 serves to smooth flat surfaces generally. All these have small studs attached to them which serve for handles.

In taking up the subject of heavy green sand moulding, we enter upon an extensive field of practice, and it will be necessary, as before, to select such examples as appear best adapted to present fair general views of the subject.

In connexion with some observations on the practice of green sand moulding generally, stated towards the conclusion of our last article, we must in the first place remark the introduction of a new element, powdered coal, namely, into the sand, in a state of simple mixture ; its office as before remarked being to assist the blackening in resisting the penetrating action of the iron. As this action exists just so long as the metal continues in a liquid state, the blackening alone proves sufficient to resist it in cases of light moulding ; whereas, in heavy mouldings, there being a much greater body of metal together, its temperature falls so much the less rapidly, and it of course continues its action as a liquid for a longer period. Consequently, coal powder in addition becomes necessary to withstand the attack of the iron. But, further, the proportion proper to be mixed is a matter of considerable nicety, and is dependent on two circumstances : first, the length of time that the liquidity of the metal continues, has a simple relation to the bulkiness of the metal ; secondly, the temperature of the metal on being poured into the mould, does proportionally increase or diminish the original

intensity of the action on the sand, as well as affect the duration of this action. The correct adjustment of this point must be left to the skill of the workman, derived from his previous experience.

A redundancy of coal in the sand renders the surface of the casting formed in it, *faint;* that is, its outlines are imperfectly developed, or, to use again the language of the moulder, the casting is not sharp. This is the natural and obvious effect of the repellent power of the superabundant gas generated by the heat from the coal. On the contrary, a deficiency of coal proves equally hurtful to the quality of the casting, as the gas produced from it is, in this case, too weak to maintain the well-balanced action of the opponent forces. The iron, having burnt through the blackening, penetrates the sand which at the surface becomes incorporated with the metal, and produces, therefore, a peculiar roughness on its surface. In order to make the casting in the most proper manner, the sand and coal-powder should be mixed, not only in a proportion suited to the body of metal to be cast in the mixture, but also as uniformly as possible.

Pease-meal is not generally used in the heavier flat mouldings, its object being to hold down the blackening applied to mouldings of an intricate or ornamental character. Now the parts of machinery generally have their surfaces plane, which are, therefore easily accessible to the trowel and sleeker.

For large castings, the bed of sand, which forms the floor of the foundery, is commonly employed for constructing the moulds, serving thereby the purpose of the *drag-box.* Our illustrative examples shall be drawn chiefly from the structure of a portable non-condensing steam-engine of 20 horse power. To begin with the sole-plate, which will be the first and most instructive example, it is necessary to describe its construction :—

Fig. 1. is an external view of the plate, showing the upper

*Fig.* 1.

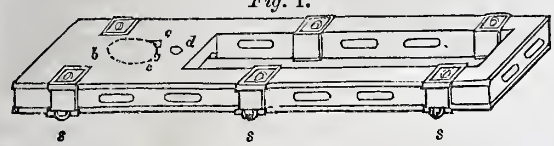


*Fig.* 2.

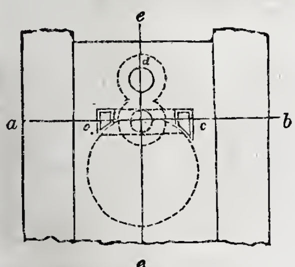


*Fig.* 6.

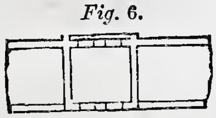


*Fig.* 5.

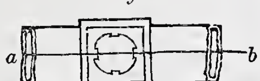


*Fig.* 3.

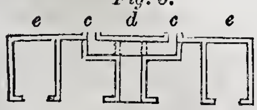
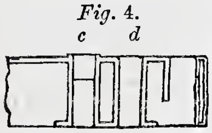


*Fig.* 4.



surface. It is arranged to maintain six columns, surmounted by an entablature. At one end *b,* a platform for supporting the cylinder is cast across the plate, stiffened by a deep flange at the edge. The position of the cylinder is indicated by the dotted circle. When the cylinder is set in its place, the apertures *c, c,* form continuations of the eduction steam passages; they are joined into one short branch-pipe below the platform. *d* is a circular passage for the introduction of the steam into the valve chest. It is projected downwards to the level of the mouth of the eduction-pipe, both passages terminating in one large flange, by which the respective pipes leading to them are connected.

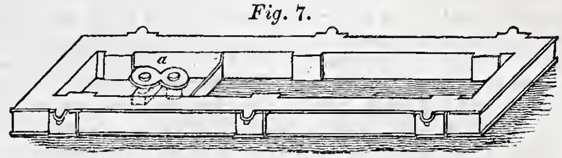
Fig. 2. is a plan of part of the sole-plate, including the steam ways, showing in dotted lines the eduction passage and the flange. Fig. 3. is a vertical section of the sole and the eduction passage at the line *a b,* fig. 2. The steam passage also is dotted in behind it. Fig. 4. is another vertical section of the same, at the line *e e,* fig. 2, showing in section both of the passages, *c, d.*

Fig. 5, is a plan of another portion of the sole, showing the foundation for a column ; fig. 6. being a vertical section of the same at the line *a b,* fig. 5. It thus appears that the sole is hollow within, and it possesses the form of section shown in fig. 3. all round, interrupted only by the sockets for the feet of the columns. It is a general practice in founding to dispose of the moulding so as that those parts of the casting towards which the greater quantity of metal exists may be undermost. In this way, greater security is found for the soundness of castings at the more important parts.

Now, the sole-plate is, for the most part, entirely open on the under side, as may be seen on referring to the section fig. 3.; it ought, therefore, to be cast with that side uppermost, according to the preceding statement.

For reasons, which will be better understood as we proceed, the pattern of the sole-plate, of the same form externally, is not made open like the sole, on the under surface. Neither are the oblong blank spaces, shown in the sides, executed in the pattern; its cross section at every point is a complete four-sided figure. This form of pattern will of course leave in the sand a plain open space of the same breadth as itself. *Cores* of sand, of the form of the internal void, must therefore be introduced into the moulding, to complete the figure of the casting. The fig. 7 ex-

*Fig.* 7.



hibits the under side of the pattern. At *a,* the patterns of the steam ways are placed. They are not fixed to the surface on which they stand, but are simply prevented from shifting laterally by small pins or snugs. They are made solid, so that they, too, like the plate itself, require to be cored out, and, accordingly, the prints, for securing the cores in their positions, are added to the patterns of the flange, which itself is attached loosely to the pipe patterns. On the opposite side of the main pattern, prints are likewise fastened to receive the other extremities of the pipe cores. In like manner, prints are attached to the upper side of the pattern, to receive the cores for the column sockets fig. 6 ; and to the snugs *s s,* &c., to core out the holes in them.

A level bed in the sand upon the floor, of sufficient extent, is, in the first place, prepared for the pattern, which is then set down upon it, and well bedded in its place, which is effected by blows given to it over the surface—the object being to form a complete impression of the under surface of the pattern. Sand is farther laid in and rammed about the pattern on all sides, till it be brought up flush with the upper side, forming thereby the parting surface, on which parting sand is strewed.

The next stage of the process is to lay the upper box or boxes, over the pattern, and to fix them in their places by stakes of wood driven into the floor, which also guide us to replace them accurately when removed. If there be not a single box large enough to embrace the whole of the pattern, two or more smaller boxes are placed end to end over it, resting upon the sand external to the moulding, and answering the purpose of a single box. The ramming of these boxes is conducted in the usual manner, except at the end *a.*

Here, it is evident, that as the platform or cylinder-plate, is now on the under side of the pattern, the body of sand filling the space immediately above it to the level of the upper side, must be lifted out to get the pattern removed. At the same time, the weight of such a deep body of sand adhering to that in the overlying box, would overcome their cohesion, it would break away altogether. As the box is therefore incapable of carrying it with it, it becomes necessary to have this load of sand supported by independent means. An iron frame is cast in open sand of the same form as the sunk space, but somewhat smaller, as allowance for the contraction of the casting, in the course of cooling, must be made to allow the plate to be withdrawn, after the casting is executed. In cases where this precaution has not been sufficiently attended to, the jamming of the plate, enclosed on

more than one side, has been the natural consequence, and sometimes the destruction of the casting by consequent fracture. In the centre of the frame, a sufficient opening is allowed for the steam ways. This frame is laid in the bottom of the recess, and as its under-surface now faces the moulding, it must be enveloped on that side in the sand, to protect it from the immediate action of the metal afterwards poured into the mould. To assist its adhesion, the frame or plate, is studded on the under side with numerous tooth-like projections, which are imbedded in the sand applied. Sand is now thrown in above the plate, surrounding the steam ways, and well rammed, its parting surface being made flush with the upper edges of the pattern of the pipe flange in the centre, and of the contiguous body of sand, forming the interior part of the moulding, their parting being just over the stiffening flange of the cylinder bottom. With this preparation, the upper boxes, as already said, are set down and filled.

There are prepared six pouring-gates to the moulding, and eight flow-gates. Of the pouring gates, or those by which the moulding is filled, two are placed along each side, about four feet distant, and two at the cylinder end of the moulding, while none are made at the other end. This unequal division is necessary, on account of the heavier nature of the moulding at the cylinder end; the design of the whole being to have the moulding filled uniformly. The flow-gates are distributed equally over the moulding. These will be again referred to.

Before lifting off the upper boxes, the pattern being now completely moulded, the latter is so far loosened in the sand, that this may not stick to it, and so spoil the operation. This is effected by gentle jolts communicated to the pattern by means of one or more pieces of rod iron, which have been screwed vertically into the pattern before finally ramming the sand in the upper box, or which merely enter into holes in the pattern. These rods being sufficiently long to pass out through the sand when the box is filled, it is upon their upper extremities that the blows of the hammer are given both horizontally and vertically; the force being regulated by the weight and magnitude of the pattern. The rods, unscrewed if necessary, are now drawn straight out, and the upper box is in readiness to be lifted smoothly off.

After the box is removed, the plate and its overlying core of sand, as it may be termed, deposited in the recess at the cylinder end of the pattern, are lifted out of their situation by arms rising through the core, carrying with them the pattern of the steam ways, which is at liberty to go; for as we have already noticed, it stands loose on the main pattern. That pattern itself is not in one piece; the flange, which is separate, is lifted off towards the upper side of the core, and the remainder of the pattern is drawn out by the under side. This is evidently the only mode of extracting the pattern, and shows the necessity in such cases of constructing patterns in two or more pieces to adapt them to the exigencies of the case.

The parts of the mould in the neighbourhood of the pattern must now after the box is removed, be pierced with small holes executed by means of wires traversing the whole body of sand, with the view of rendering the moulding more porous, and of facilitating thereby the escape of the air and other gases. The mould is also watered along the edges to increase the coherence of the sand.

The pattern itself is taken out by lifting it in all its parts at once by pins secured into it at several places, so as to be raised in a truly vertical position. This manœuvre is performed by several men, who, while they lift the pattern with one hand, strike it gently and constantly with the other, thus continually checking any efforts made by the pattern to tear away the sand of the moulding, and now especially is this remedial application necessary, as the pattern is much more engaged in the lower moulding than in the upper, which indeed is the case in mouldings generally. Unavoidable degradation in one or other of the two parts of the mould nevertheless do occur, and these the workman repairs with damp sand by means of his trowel.

The moulding is next smoothed all over the surface by the trowel, and a sprinkling of charcoal is then applied and polished likewise by the trowel. It is, however, omitted for very large castings. Sometimes also, in order to avoid using too much charcoal, the surfaces are lightly dusted over with sand finely pulverized, through a bag. The moulding is now ready for the reception of the cores, the making and depositing of which claim the particular attention of the moulder, as the figure of the future casting will very much depend upon his accuracy in these respects.

Cores of several forms are necessary for the completion of the moulding. There are, first, the cores for the column sockets, of which there are six; then the cores for the intermediate portions of the sole-plate, of which also there are six, there being two on each side between the socket cores, and one at each end; again, two cores for the steam ways, with several other minor cores, for the holding-down-bolt holes in the snugs at the bases of the columns, as well as for the holes that may be required for the bolting down of pedestals, &c., to the sole. For all these, there are simple prints sprigged upon the pattern at the proper places, the impressions of which in the sand serve to hold the cores securely.

As we have already remarked about the beginning of our last paper, cores must be made not only of the exact size and shape of the vacancies in a casting, whether partial or thorough, which they are intended to form; allowance must also be made on them for the core-prints, when these are necessary. This allowance then is provided in the cores for the column sockets, for which there are prints on the under side of the pattern, fig. 7. These sockets go through the sole, and are square in the body, and round at each end, as may be understood on referring to figs. 5 and 6, and to the annexed fig. 8, which is a plan of the moulding, showing the cores in their places.

*Fig. 8.*

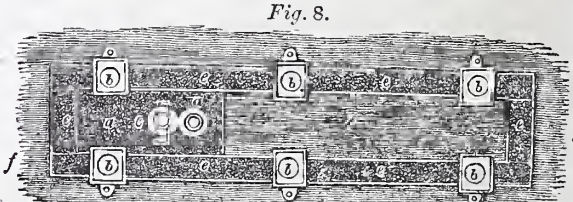



*Fig. 9.*

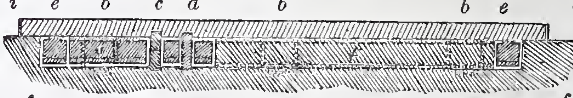



Fig. 9, is a longitudinal section of the moulding, taken through the steam ways. In both figures, *f f f*, is the sand of the floor, in which the moulding is formed, constituting the interior as well as the exterior of it; *b*, *b*, &c, are the cores of the column sockets, seen in dotted lines in the section; *c*, *d*, are the cores for the steam ways which in fig. 9 are seen projecting into the sand, above and below filling the recesses made for them by the prints. Figs. 2, 3, 4, explain the shape of them. They are formed in boxes, which open in two, for the purpose of extracting them. These, with all the other small cores, are dried upon hot plates, heated by stoves. At *a*, and *e*, *e*, &c., the cores are shown, forming the spaces in the moulding intended to be vacant. Near the under side of each, in fig. 9, are shown the plates, indicated by dark lines, which sustain the cores. The whole, however, must be sustained by the bottom of the moulding, leaving a space of the required thickness of the casting. This is effected by placing steeples there; these are simply strips of sheet iron of small lengths, but with double knees, thus [. If the depth of these be just the thickness of the metal, then by placing several of them along the bed of the moulding, they support the cores placed over them, keeping the space clear for the metal—of course these steeples will be imbedded in the casting, where they are allowed to remain. The double-knee cores at both ends of the moulding, it will be observed in fig. 8, are put together, each in three pieces. In constructing the cores *e*, *e*, &c., plain square bodies of sand of the dimensions of the interior of the casting, are in the first place formed in boxes of the same size, including at the same time the iron frames enveloped in the cores. Now the small cores that are necessary to the oblong openings in the sides of the casting are simply attached in their proper positions to the sides of the main cores *e*, *e*, &c. They are formed and fixed on by simply applying upon the larger core, an open box of the form required, into which sand

is packed, thus causing it to adhere to the main core; when the box is filled, the sand is squared off by a straight edge flush with the surface of it. It is evident that if the box be lifted off, it leaves its core behind it. All the other smaller cores having been made and set in their places, the moulding is finally closed, the upper box being replaced, as seen in section *i i*, fig. 9. This requires to be done cautiously and in a truly vertical direction, as it now receives the upper ends of the cores which project above the moulding, and also bears upon the other cores large and small which do not require any additional security.

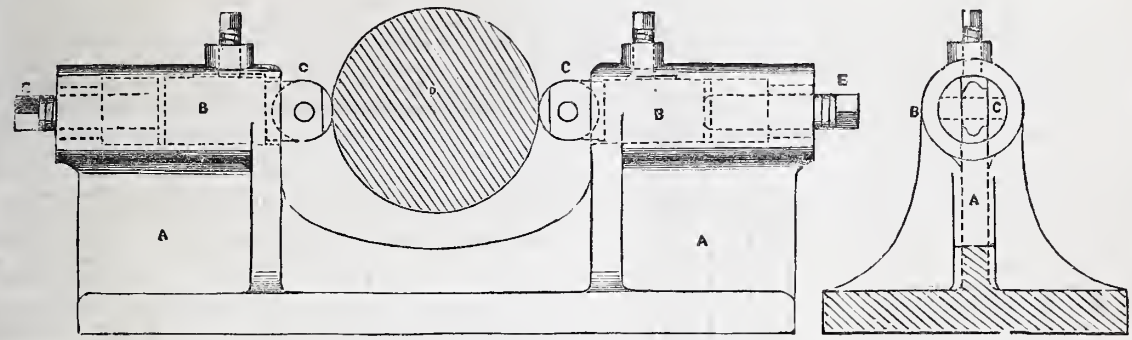
When convenient, two or more gates are connected to one central reservoir, all built on the surface of the sand. Gates at considerable distances from others, are usually supplied separately with iron from hand ladles. The other gates that are connected are supplied from crane ladles, which are conveyed by cranes from the cupola to the moulding. The ladles will be afterwards described. The flow-gates, while the metal is being formed, are plugged with clay-balls, to "keep down the air" in the moulding. These plugs are drawn out when the moulding is filled, and the iron flows up. It is thus judged whether the casting is complete. The plugs must not be prematurely drawn, as by the too free egress given to the air, the bottom of the mould is apt to be disturbed by the air confined in the sand.

When the metal is poured, the "feeders" are immediately applied at the flow-gates. These are rods of iron, which are plunged into the liquid iron, and wrought up and down in it. By this agitative process, the liquidity of the iron about the gates is longer than otherwise maintained. It is therefore enabled to supply itself with additional iron from the flow-gates, for it must be understood that in the cooling down of large bodies of metal, the surface sets, while the interior is liquid; and therefore when the interior farther contracts, it draws in the surface metal towards the centre, and if not fed as above described, the casting assumes a vesicular structure, which weakens it considerably. To avoid such a result as far as possible, is the object of the agitation produced by the rod.

## MACHINE FOR CONDENSING THE SURFACE OF BRASS ROLLERS.

It is pretty generally known by parties connected with the finishing and smoothing of cloth goods, that great inconvenience is felt by the frequent failure of the brass and paper rollers used in the mangling machines.

The enormous pressure to which these portions of the machinery are subjected, together with their almost ceaseless working during busy periods, contribute greatly to these casualties, it being no unusual thing to put a pressure of 20 or 30 tons upon them. The consequence is, that the metal speedily laminates out, and the whole mass crumbles away. Our engraving annexed, exhibits a simple arrangement, by which the roller may be considerably solidified so as to enable it to act efficiently for a much longer




period than a plain cast-metal one. A A is a plain cast-iron bracket having two long eyes cast on the upper portions of its two ends, in which the slides B B are loosely fitted. The ends of these slides are grooved for the reception of the steel compressing rollers, C C, which are capable of adjustment, to suit any diameter of roller, by the set screws E E. The latter work in nuts fixed in the eyes, their inner ends abutting against the ends of the slides B B; the rollers can thus be made to act with considerable power upon the roller D. This apparatus is extremely easy of application, the bracket being arranged to bolt on to the slide rest of a lathe, is traversed along its bed, at the same time that the roller revolves slowly upon its own axis.

## NATURAL PHILOSOPHY AND CHEMISTRY.

### CHAPTER IV.

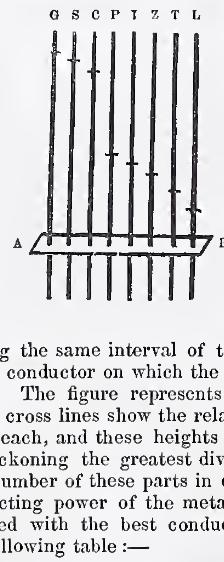
#### CONDUCTION AND RADIATION OF HEAT.

One of the most important properties of heat is its tendency to equal diffusion. This is a subject of our most common observation. Our sensations inform us of it in a rude way, and the thermometer enables us to determine the fact with accuracy. In studying the circumstances of the diffusion, we are however speedily satisfied that an equality of temperature is not established among bodies unequally heated, when placed in the vicinity of one another, by one and the same process. The first mode of distribution which attracts our notice is *radiation;* for the whole course of our experience proves to us that heated bodies throw off *rays* of heat precisely as luminous bodies throw off rays of light. But this respects only the loss of heat by a hot body, whereas the acquisition of heat by a cold one is a consideration of equal importance. As the particles even of the densest matter are not in absolute contact, we might indeed regard the propagation of heat through the substance of a solid, when it is raised from a lower to a higher temperature, as the effect of internal radiation from particle to particle of the mass; but we are too imperfectly acquainted with the molecular structure of bodies, to know positively what takes place between their particles, and there are other circumstances attending these modes of diffusion, which in the present state of our knowledge render it difficult to comprehend them both in the same physical explanation. For the sake of simplicity, it is therefore usual to distinguish between the distribution which takes place within and without a mass, and it is into the nature and laws of these processes which we are now about to inquire.

*Conduction of Heat.*—This is the term which we employ to denote the process by which heat passes from particle to particle of a substance, without changing their relative positions. Perhaps all bodies in nature are thus pervious to heat; for no substance has yet been discovered, which will, for any length of time, contain or confine that modification of heat and of cold which is sensible to the feelings and to the thermometer.

But here a question arises:—does heat enter and leave all bodies with the same facility? The answer is furnished by everybody's experience. When one end of a rod of iron is held in the fire, a hand grasping the other end soon feels the heat coming through it, and by-and-by it cannot be laid hold of at twelve inches from the part where it is red hot, without danger of being burned; yet this may be done with all safety with a rod of glass at a distance of three inches from its red hot extremity; and we can hold a piece of burning charcoal in the hand with no disagreeable sensation of heat, even when the burning part is only a few lines from the fingers. The explanation is this: the iron allows the heat to permeate rapidly through its substance, and consequently supplying it rapidly to the hand, produces pain by its great accumulation there; whereas the glass allows it to pass slowly, and the sensation is feeble because there is *little* accumulation; and again in the case of the charcoal and substances of a like nature, the passage of the caloric is so tardy, that the sensation produced by one portion of it has ceased before another commences—there is *no* accumulation.

As different bodies, then, possess this property of conducting heat through their substance in very different degrees, it becomes important to ascertain the relations which they bear to each other in respect of this property. From common observation we learn, in a general way, that the most dense bodies are the best conductors, and that the conducting power decreases as the density becomes less. Thus metals are the best conductors; next stones; next hard woods, and so on down to wool, silk, feathers, fur, and the like, which are very bad conductors. But more careful investigation shows that the observation, though generally, is not universally, correct; the metals themselves show this in a remarkable degree. Platinum, for instance, is about two and a half times heavier than copper, bulk for bulk; yet if equal portions of wire of these metals be held by one of their extremities, while their other extremities are in contact with the flame of a candle, the copper will burn the fingers before the platinum gives almost the slightest sensation of heat. This experiment may be extended to other metals, and the following modification of it shows very conclusively, the conducting power of the metals employed. Wires of gold, silver, copper, platinum, iron, zinc, tin, and lead, of exactly the same size and length, are fixed at equal distances in a slip of wood, A, B, through which they pass perpendicularly. The wires above the binding slip of wood are covered with a thin coating of wax, which is readily given to them by dipping them into melted wax. Thus prepared, the experiment is completed by plunging the part of the wires below the wood into heated oil, and noting to what distance the wax is melted on each wire during the same interval of time, that metal being reckoned the best conductor on which the wax is melted to the greatest height. The figure represents the arrangement of the wires, and the cross lines show the relative heights to which the wax melts on each, and these heights may be converted into numbers by reckoning the greatest divided into a thousand equal parts; the number of these parts in each height will then express the conducting power of the metal on which it is measured, as compared with the best conductor. These relations are shown in the following table:—




| | | | |
|---|---|---|---|
| Gold, | 1000 | Iron, | 374.3 |
| Silver, | 973 | Zinc, | 363 |
| Copper, | 898 | Tin, | 303.9 |
| Platinum, | 381 | Lead, | 179.6 |

The form of the experiment above described is that suggested by Dr Franklin, and executed by Dr Ingenhouz; but the numbers in the table are derived from the experiments of M. Despretz, which were executed with the utmost care.

Another form of the experiment described, and that usually adopted by lecturers when showing the comparative conducting powers of the metals, is to reject the covering of wax, but to fix on the top of each wire an exceedingly small portion of phosphorus, and observe the intervals of time elapsing between the kindling of the phosphorus by the different metals: these intervals may readily be calculated from the foregoing table.

Further experiments show that after the metals, diamond, glass, hard stones, porous earths, and woods, are the next best conductors; but the difficulty of conducting experiments upon them renders the results very doubtful. It is found also, that there is a considerable difference in the conducting power even of the same material, according to the state in which it is employed. Thus we have stated that metals are good conductors, yet their filings are very inferior in conducting power; and whatever conducting power wood may have, it is much lessened by being converted into sawdust, and still further by conversion into ashes. Solid stones transfer heat with some facility, but the conducting power of sand is so little, that the red hot balls used at the siege of Gibraltar were conveyed from the furnaces to the bastions in wooden wheelbarrows, covered with only a layer of sand. These are instances where the conducting power is much decreased by breaking the cohesion of the bodies; and other cases might be cited to show that the conducting power is much increased by increasing the compactness of the structure. For instance, glass and porcelain are better conductors than the materials of which they are made.

It is the difference of the conducting power in bodies which is the cause of the erroneous judgment which we are apt to form of the temperature of bodies by the touch. If we apply the hand at the same time to a good and to a bad conductor, such as a metal and a piece of cork, which are exactly the same temperature, the good conductor will give a more vivid sensation of heat or cold than the bad conductor. For instance, in a room without a fire, all the articles of furniture soon acquire the same temperature; but if the hand be first applied to the carpet, or other article of a like nature, then to a table or other article of wood, next to the stone mantelpiece, lastly to the iron fender, the sensation will deem each of these objects in succession colder than the preceding: the carpet being the worst conductor, it will convey away the heat from the hand less rapidly, and consequently in less quantity in a given time, and therefore will feel least cold; whereas the iron of the fender, being the best conductor, will convey away the largest quantity of heat in a given time, and will therefore produce the greatest sensation of cold. Were a similar experiment made in a stove-room, where the actual temperature of everything is greater than that of the body, the reverse would be perceived: articles of cloth would give a feeling of gentle warmth; wood would be considered warmer, and iron hot; and the reason is, that the material which has the least power of conduction, permits a less quantity of heat to pass in a given time from its interior and enter the hand, than those substances in which the conducting power is greater.

These considerations are practically applied in some very familiar instances: as when a wooden handle is used for a tea-kettle, to protect the hand from heat; and when the handle of a winch is covered with a cylinder of wood, to protect the hand from cold. They also make manifest the popular error, that there is a positive warmth in the materials of clothing. Flannel, for instance, is among our warmest articles of winter dress, yet we cannot more effectually preserve ice in summer than by wrapping it in folds of flannel. Indeed the whole philosophy of clothing consists in enveloping ourselves in materials which resist the passage of heat most effectually, both from within and without; that is, in materials which have the least conducting powers; and in this respect, the general practice of mankind seems to be correct. The reason is, that in cold weather the temperature of the atmosphere is lower than that of the body, and the clothing of non-conducting materials prevents the too rapid escape of the heat from the body to the surrounding air; and, in very hot weather, it answers a contrary purpose: it prevents the too rapid communication of heat to the body. Thus the thick cloak which guards the Spaniard against the cold of winter, protects him in summer against the direct rays of the sun. But in a mild climate, the quantity of clothing requires to be moderate: if too thick, the heat of the body accumulates and becomes oppressive; and, if too thin, the heat escapes too quickly, and a sensation of cold is induced. There are however other circumstances to be taken into consideration, and which will be better understood when the radiation of heat is under discussion.

Nature has provided admirably for the inferior animals in respect to clothing. In warm climates the hairy coat of quadrupeds is comparatively short and thin, and this is seen to thicken

with increasing latitude, furnishing a thorough protection to the wearers against the chills of night and the blasts of winter, in those regions which we call temperate, and the eternal ice and snow of the arctic zone. The covering of amphibious animals is peculiarly defensive; and birds, from having very warm blood, require plenteous clothing, but require also to have a smooth surface, that they may pass easily through the air: both objects are secured by the beautiful covering of feathers,—so beautifully and so admirably adapted to its purposes, that writers on natural theology have often particularized it as one of the most striking exemplifications of creative wisdom. The birds of cold regions have, moreover, plumage almost as bulky as their bodies; and those of them which live much in water have additionally, both a defence of oil on the surface of the feathers, and the interstices of the ordinary plumage filled up by the still more delicate structure called down, particularly on the breast, which, in swimming, first meets and divides the cold wave. There are animals with warm blood which yet live very constantly immersed in water, as the whale, seal, and walrus; and neither hair nor feathers, however oiled, would have been a fit covering for them; but kind nature has prepared an equal protection in the vast mass of fat or blubber which surrounds their bodies—a substance scarcely less useful to them than the furs and feathers of land animals.* Even the covering of trees—the bark, is a substance very slowly permeable to heat, and has its use in securing the temperature necessary to the maintenance of vegetable life.

Count Rumford made an elaborate series of experiments to determine the fitness of various substances as articles of clothing. His plan was simple and ingenious. He suspended a thermometer in a glass cylinder blown into a bulb at its extremity, the bulb of the thermometer being placed in the bulb of the cylinder, and carefully surrounded with the substance, the conducting power of which was to be ascertained. Having heated the apparatus to the same temperature, in every instance, by immersion in boiling water, he transferred it into melting ice, and observed carefully the number of seconds which elapsed during the fall of the mercury in the thermometer through 135 degrees. The results are shown in the following table:—

| Surrounded with | Seconds. | Surrounded with | Seconds. |
|---|---|---|---|
| Twisted silk, | 917 | Beaver's fur, | 1296 |
| Fine lint, | 1032 | Eider down, | 1305 |
| Cotton wool, | 1046 | Hare's fur, | 1315 |
| Sheep's wool, | 1118 | Wood ashes, | 927 |
| Taffety, | 1169 | Charcoal, | 937 |
| Raw silk, | 1284 | Lampblack, | 1117 |

Bearing in mind that the worst conductors are those substances which take longest to cool, it will here be observed that twisted and raw silk differ very materially in this respect to their powers of conduction; and throughout all the experiments, although not recorded in the table, it was found that the conducting power of a substance differed according to the closeness and openness of its texture. Common experience proves the same. Thus, soft flannel is much warmer as an article of clothing, than fabrics of hard twisted worsted, and the same is true of several fabrics of cotton silk.

Lampblack and a piece of charcoal we know to be chemically one and the same substances; yet we observe that there is a very considerable difference in their powers of conduction, and which can only depend on their degrees of porosity. The almost non-conducting nature of soot, which is only an inferior sort of lampblack, is illustrated by the well-known experiment of placing a tea-kettle of boiling water just taken from the fire, upon the palm of the hand: when it is well coated with soot—and this is essential to the success of the experiment—the transmission of heat to the hand is so exceedingly slow that no disagreeable sensation is experienced.

Mr Lyell cites a remarkable instance illustrative of the bad conducting powers of volcanic ashes, in the preservation of a glacier near the summit of Mount Etna. This glacier is covered by lava which must have flowed over it in a state of fusion, and its only protection from the enormous heat of the superincumbent mass was, a dense covering of fine volcanic dust which had been thrown over it, by the eruption of the mountain before the descent of the lava. It is in the same way that the shepherds, in the higher regions of Etna, are still accustomed to provide water for their flocks during summer. "They strew a layer of volcanic sand a few inches thick over the snow, which effectually prevents the heat of the sun from penetrating to the snow and melting it."

Advantage is taken in the arts of the imperfect conducting powers of substances to confine heat. Thus, a smelting furnace is lined with fire-brick to prevent the waste of heat; a covering of various mixtures of clay and sand, and sometimes powdered charcoal, is employed for the same purpose; and to prevent during winter the freezing of water lying in pipes, the pipes are covered with strawbands, coarse flannel or the like; or sometimes they are enclosed in other larger pipes, the interval between the two being filled up with powdered charcoal, sawdust, chaff, or other imperfect conducting material. When pipes are destined to convey steam or other warm fluid, the heat is retained by the same means. Exactly the same methods are resorted to for exactly the opposite purpose, as when ice-pails and ice-houses are made double, and the intervals filled with charcoal, chaff, straw, and other bad conductors. Operators also, who have frequently to touch or handle substances which are hotter or colder than is agreeable, find it convenient to provide themselves with worsted gloves to protect the hands, the worsted being a bad conductor.

From the facility with which liquids acquire heat, under particular circumstances, it might be hastily concluded that they possess the power of conduction in a very high degree; but the reverse is proved by experiment, and the facility noticed depends upon the change of density which they undergo, by alteration of temperature, and the mobility of their particles as already described. (Chap. iii. p. 67.) The common mode of applying heat to liquids, is to apply it to the bottom of the vessel containing them, and it is speedily carried through the mass by the currents which are immediately established, in consequence of the successive changes of density which result from the expansion of the heated portions; but if the heat be applied at the surface, no interchange of strata, analogous to that described, can take place; for the heated portion being lighter than the cold water beneath remains at the surface. For instance, if a glass tube, of 5 or 6 inches in length, be nearly filled with water, and heat be applied to the upper part, by holding it obliquely over the flame of a lamp, the water will boil upon the surface, while we hold the under part of the tube in the hand without inconvenience, which can only be from the water conducting the heat downward, very slowly. The experiment may be made with greater precision, by placing the bulb of a very small air-thermometer some distance below the source of heat,—the descent of the liquid in the thermometer will be extremely slow. Every form, however, of this experiment, conducted in a tube of glass, or other conducting material, is inconclusive; for the heat is ultimately conveyed downward through its substance, and communicated to the contained liquid. To avoid this source of error, a vessel of ice has been substituted, and the heat applied by pouring boiling oil into a capsule, floating in the contained liquid. Even this does not exempt the experiment entirely from fallacy, and indeed the question is one of considerable difficulty, but it has nevertheless been proved by delicate and ingenious means, that liquids *do* conduct heat, and that like solids, they conduct it better in proportion as they are more dense. Thus: spirit of wine is a very light fluid, and a bad conductor among fluids; oil is heavier, and conducts better; proof-spirit is heavier, and is a better conductor; water is still heavier, and is a still better conductor; and mercury, the heaviest of all liquids, is comparatively an excellent conductor of heat. The difference of time which a hot body takes to cool, when immersed in these several liquids, affords a very rough estimate of their relative conducting powers. For instance, if three pieces of iron, of exactly the same size, form, and temperature, be plunged into equal quantities of oil, water, and mercury, it will be found that the piece in contact with the oil will cool more slowly, and that in contact with the mercury will cool more rapidly than that in contact with the water; thereby showing, that the oil is a worse, and the mercury a better, conductor of heat than water. This explains the practice in the manufacture of steel instruments, of cooling one sort of instrument in oil, another in water, and a third, which is to be more than ordinary hard, in mercury—the hardness of steel depending on the rapidity of its cooling.

* Arnott on Heat. Some human animals are provided for in the same way. A very fat man is much less liable to inconvenience from cold, than one whose adipose covering is scanty.

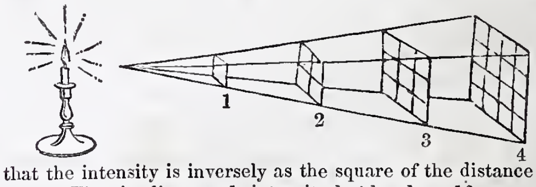
Air and gases are still more imperfect conductors of heat than liquids, and indeed it has never been satisfactorily proved, that they have any conducting power at all. It is ascertained, however, that hot bodies cool more rapidly in some gases than in others: in hydrogen, the cooling goes on twice as rapidly as in common atmospheric air, and more quickly in atmospheric air than in carbonic acid gas (choke damp). This goes far to prove the existence of the power of conduction; and certain ingenious experiments, made by Dulong and Petit, are generally allowed to have established, not only the fact, that gases, like other bodies, are conductors; but that the conducting power bears a discoverable proportion to the elasticity, diminishing as the elasticity diminishes, and increasing as the elasticity increases.

A very simple experiment may afford a rough estimate of the comparative conducting powers in the three classes of solid, liquid, and aeriform bodies. Metals heated to 150 degrees will severely burn a hand placed upon them; water will not scald, provided the hand be kept without motion in it, till it reaches a temperature of 180 degrees, while the contact of air can be endured without any painful sensation, when heated up to 300 degrees. There is an experiment upon record in the *Philosophical Transactions*, by Sir Joseph Banks and others, who ventured into a room heated up to 260 degrees; and remained there some time without serious inconvenience; and Dr Arnott relates that he entered a room where there was no fire, but where the temperature from hot air admitted, was sufficient to boil the fish, &c., of which he afterwards partook at dinner in another room, and that he could breathe the hot air without uneasiness. But these experiments are not more worthy of being recorded than those which are being made every day, in several processes of the arts, where it is necessary for workmen to enter stoves heated as high as 300 degrees, and no injurious effects follow. Under such circumstances, all contact with liquid and solid substances require to be carefully avoided, or severe injury would be sustained. The same property of non-conduction also preserves the body, in the opposite extreme of temperature. The late voyages in the arctic regions prove, that a cold of 16 degrees below that which freezes mercury (namely,—55°,) may be sustained without injury, provided the atmosphere be still; but if there be any wind, the successive contact of fresh particles, even when the temperature is much higher, will abstract heat with such facility as to freeze the extremities.* Indeed, the whole cause of the extraordinary resistance which the human body offers to these extremes of heat and cold is this: the body preserves a uniform temperature of 98 degrees, so long as its vital functions are in a healthy state, and without regard to the temperature in which it lives; and therefore when brought into contact with hot or cold air, a thin layer of the air is brought to the same temperature as the body, and remaining in contact with it, acts by its non-conducting quality, as a protection against the heat or cold of the general mass: in the case of winds, or of the rapid movement of the body, this protecting envelope is displaced. That this is the reason why winds produce so keen a sensation of cold may be proved by an experiment of an opposite kind: let the hand be introduced very gradually into hot water, as hot as can conveniently be endured, and then attempt to move it briskly about, so as to bring it into contact, rapidly, with fresh particles, the heat will be felt to be intolerable. An intense sensation of cold is also felt, by moving the hand rapidly about in cold water.

It is owing to the non-conducting property of air, that loose clothing is warmer than such as fits closely, a quantity of the air being confined round the body, resisting the escape of heat; and, indeed, all articles of dress seem to be warm in proportion to the quantity of air which they contain in their texture: thus, cloth having a long nap, furs, wool, down, and feathers, involve a large quantity of air, among the parts of which they consist; and we have already stated, that they afford excellent protection against cold. The imperfect conducting power of snow arises from the same cause; and it is of the greatest utility in preventing the surface of the earth from being injuriously cooled in many parts of the world. It is affirmed, for instance, that while the temperature of the air of Siberia has been 70 degrees below the freezing point, the surface of the earth, protected by its covering of snow, is rarely below the point of freezing. We also take advantage of this property of air, to put double doors, enclosing a body of the non-conducting material on our furnaces, to prevent the escape of the heat outward; and double windows are used in some large buildings, for the same purpose, in winter; and the reverse in summer. It has likewise been ascertained, that the conducting power of air, saturated with moisture, is to that of air thoroughly dry as 3 to 1;† hence, the former feels so much colder to the human body, and renders a "*raw* atmosphere" very disagreeable, even when the actual temperature is mild.

*Radiation of heat.*—When a red hot ball is suspended in the middle of a room, it propagates heat in every direction around it, just as it propagates light. This cannot arise from the conducting power of the surrounding air; for the conducting power of air is extremely small, and that which is actually heated by contact with the ball, and which alone could be supposed to convey any great quantity of heat, is directed upwards in an ascending current from its rarefaction as formerly explained, when speaking of the diffusion of heat in liquids and aeriform bodies. From this emission of heat from the surface of the hot body in straight lines and apparently in actual quantity and from every point, we speak analogically of the *rays* of heat, just as we do of those of light, and we call the mode of propagation, *radiation*, and the heat which is radiated, is *radiant heat*. But rays of heat are emitted from the body for a considerable time after it has ceased to emit light, and the heat still follows precisely the same laws as when the body was luminous. The only difference is in intensity between the heat from a red hot ball, and from the same ball when cooled to blackness: the rays traverse the air in both cases in the same manner, and communicate heat to all the bodies around, but in different degrees, until by the process of cooling, the body has sunk to the same temperature as the medium in which it is placed. The ball moreover, although placed in a vacuum, dissipates its heat and cools rapidly, emitting its heat in every respect as when placed in air, and falls exactly to the same temperature as the external medium. This fact proves not only that heated bodies do radiate in vacuo, but that radiant heat, whatever it is, is capable of being propagated independently of conduction.

The law of central force already noticed under the head of attraction, (page 36) is that which radiant heat obeys: namely




that the intensity is inversely as the square of the distance:

That is, distance 1, intensity $\frac{1}{1}\times\frac{1}{1}=\frac{1}{1} = 1^2$

distance 2, . . $\frac{1}{2}\times\frac{1}{2}=\frac{1}{4}=(\frac{1}{2})^2$

distance 3, . . $\frac{1}{3}\times\frac{1}{3}=\frac{1}{9}=(\frac{1}{3})^2$

distance 4, . . $\frac{1}{4}\times\frac{1}{4}=\frac{1}{16}=(\frac{1}{4})^2$

and so on. This is at once obvious both for light and heat, from a mere inspection of the figure, and the explanation already given.

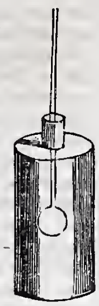
The power of radiation is very different in different bodies. This is obvious from the circumstance that some bodies when highly heated, are more speedily cooled down to the temperature of the medium in which they are placed, than others. And this is found to depend more on the mechanical state of the *surface*, than upon the nature of the *substance* of the cooling body. A simple experiment establishes this fact very satisfactorily. By providing two cylindrical vessels of tin-plate, similar to that represented in the margin, and capable of holding about a pint each, and painting one of them with lamp-black mixed with water and a little size, and fitting each with a small thermometer passing

* Captain Parry, under the date of Tuesday, the 15th of February, 1820, says, "From four p.m. on the 14th, till half-past seven on the following morning, viz., an interval of fifteen hours and a half, during which time the weather was clear and nearly calm, a thermometer, fixed on a pole between the ships and the shore, never rose above 54°, and was once during that interval, namely, at six in the morning, as low as 55°, (that is, 87 degrees below the freezing point of water.) * * * During the lowest temperature above mentioned, which was the most intense degree of cold marked by the spirit thermometer, during our stay in Winter Harbour, not the slightest inconvenience was suffered from exposure to the open air, by a person well clothed, as long as the weather was perfectly calm: but in walking against a very light air or wind, a smarting sensation was experienced all over the face, accompanied by a pain in the middle of the forehead, which soon became rather severe. We amused ourselves in freezing some mercury during the continuance of the cold weather, and by beating it out on an anvil, previously reduced to the temperature of the atmosphere; it did not appear to be very malleable when in this state, usually breaking after two or three blows of the hammer."—*Voyage for the Discovery of a North-west Passage.*

Captain Ross has more lately observed a temperature so low as 60°.

† Accurately, 230 to 80$\frac{2}{3}$. Rumford, Phil. Trans., 1786.

through a cork adapted to the mouth; we are in possession of an apparatus similar to that with which Sir John Leslie made several of his most important observations on the radiation of heat. When both vessels thus prepared, are filled with boiling water at the same instant, and the corks and thermometers immediately introduced, we might suppose that the rate of cooling would go on equally in both vessels, and if we did admit of the probability of an unequal dissipation of heat, there is everything to induce us to think that the painted vessel, being covered with lamp-black, a non-conductor of heat, and which is the least warm to the touch, would allow the heat of the water to escape much more slowly than the highly polished vessel, which gives a sensation of far greater heat when the hand is placed upon it. But the fact is exactly the reverse: the thermometer of the blackened vessel sinks rapidly, while that of the bright one falls very slowly; and as there is supposed to be no other difference in the cylinders than that the one is painted black, and the other is not, we are justified in concluding, that a surface of lamp-black radiates heat more freely than one of polished metal.

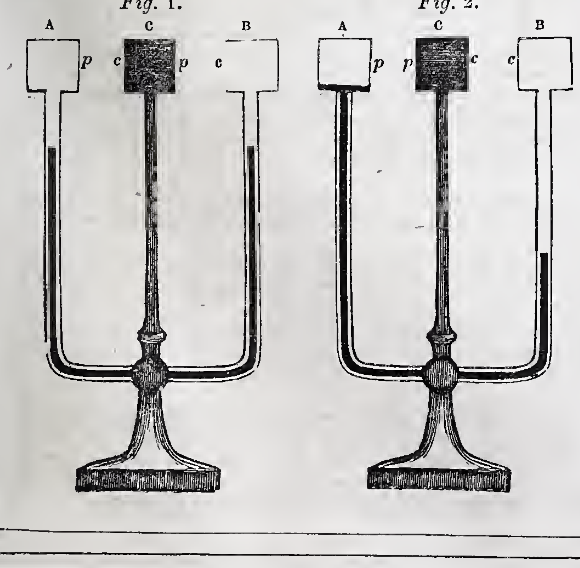


The same experiment may be made with thermometers only, one having the bulb blackened, and the other being left clean. If both be raised to the same temperature before a fire, and then allowed to cool, the mercury in the blackened one will sink at a much quicker rate than that in the other. But a still simpler way of proving the fact consists, in smoking one side of any convenient tin vessel over the flame of a candle or oil-lamp, and leaving the other side clean and polished; if a vessel thus prepared be filled with boiling water, no thermometer is requisite to show that more heat is radiated by the blackened surface than the metallic one; for the hand brought *near* the former, receives a much greater impression of heat than when it is at an equal distance from the latter.

These experiments prove decisively that the radiating power of a body is altered by altering the mechanical state of its surface; and a very slight modification of them shows us satisfactorily, that the absorbing power of a body is altered in the same way. For instance, if instead of filling the two cylindrical vessels with hot water, we fill them with water at the ordinary temperature, and place them before a steady fire, the thermometer of the blackened vessel will rise much more rapidly than that of the polished vessel; and similarly, the mercury of a thermometer, when the bulb is smoked, absorbs heat more quickly than when it is clean. From these facts it appears, that bodies which radiate heat best, absorb heat likewise with greater power; and those which when hot cool most slowly, are those which have the least tendency to receive heat.

The mutual relation of the absorbing and radiating powers can even be proved experimentally to be exactly proportional to each other. The method is this:—a large differential thermometer is constructed, having the glass bulbs replaced by cubical vessels,

*Fig.* 1. *Fig.* 2.




A and B, of equal size, and so arranged that the two surfaces opposite to each other shall be exactly parallel. Of these, one, A, is polished, and the other, B, is coated with lampblack. Midway between them is placed a similar vessel C, having one of its faces highly polished, and the opposite one coated as before with lampblack. This vessel is placed on a vertical axis, so that any of its plane surfaces may be placed parallel to the interior plane surfaces of the vessels answering to the bulbs of the thermometer: thus, its coated surface can be placed opposite to the polished surface of the bulb, as supposed to be shown in fig. 1, or opposite the coated surface of the bulb, as represented in fig. 2. When a hot liquid, as oil, is poured into the intermediate vessel, when the apparatus is arranged as in fig. 1, no effect on the thermometer is perceived; for the respective actions of the surfaces exactly balance one another; the better radiating surface is directed to the worse absorbing one, and the worse radiating to the better absorbing; and radiation and absorption being equal, the liquid in the tube of the thermometer remains perfectly stationary. To prove that this is the true explanation, it is only necessary to turn round the vessel to the position shown in fig. 2. Where like surfaces are opposite each other; that is, metal to metal, and black to black, an immediate effect is perceived. In this case the worse radiator is opposed to the worse absorber, and the good radiator to the good absorber, and consequently everything is favourable to the effect on the one side, and opposed to it on the other: the liquid of course ascends in the stem of A, and descends in the stem of B.

There is another form of this experiment, which, although not equally exact, shows very decisively the relation between radiation and absorption. The apparatus consists of a cylindrical tin-

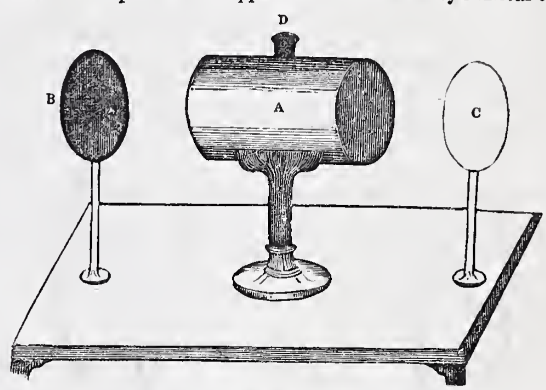
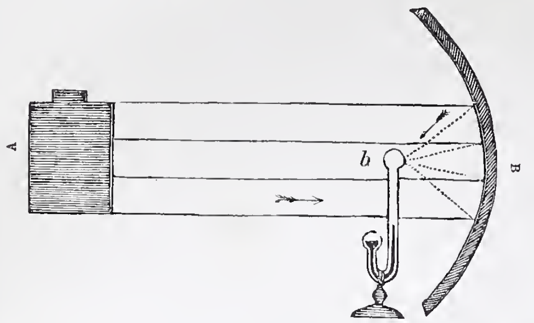



plate vessel, A, having opposite its ends two tin-plate discs, B and C, one of which, C is bright, and the other, B, is painted with lampblack and size-water on the surface next the cylinder. These discs are stuck by means of a thin stratum of lard upon second discs which are soldered to the stands, and the ends of the cylinder are, one coated and the other bright. When the cylinder is filled with hot water through the mouth D and corked, if the good radiator and bad absorber, and the bad radiator and good absorber are placed opposite to one another, the discs will drop off exactly at the same time, thereby proving that radiation and absorption are co-existent and co-equal; but if the apparatus be differently arranged, the effect will be different: the absorbing disc will drop off before the temperature of the other is felt to be in the slightest degree elevated, and this last indeed will not likely separate during the experiment.

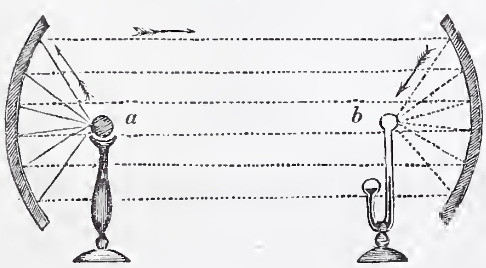
It will naturally be inquired what becomes of the heat which is radiated upon the polished metallic surface, and refused admittance. We can readily know that it does not pass through the metal: it must therefore pass off in some direction without penetrating the surface. This difficulty is easily removed by substituting for the plane polished surface a concave reflector, B, which will be found to collect and concentrate the rays of heat from the tin canister A, which is filled with hot water, into one point at *b*. This is proved by placing the upper bulb of a differential thermometer at that point; the liquid instantly begins to descend in that stem, and to rise in the other. Even this degree of nicety is not requisite to prove the mere fact of reflection. If the commonest tin reflector, at all approaching to a parabolic form, be held some feet from a large fire, and the finger be put in the focus, a very considerable warmth, depending on the amount of

radiation will be perceived. And for experiments, where great accuracy is not required, as plated copper reflectors are expensive, and even hammered tin reflectors not everywhere easily procurable, reflectors of 15 inches diameter, cast of plaster of Paris and gilt or silvered on their concave surfaces, will serve for all common illustrations.



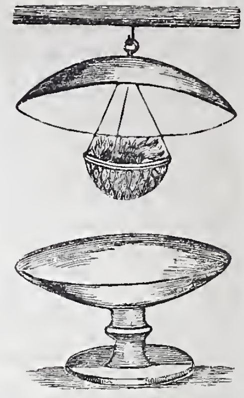

The apparatus shown in the figure above is that with which Prevost and Leslie made most of their experiments upon the radiating power of different bodies; and, with the aid of the differential thermomoter, nothing more is wanted to arrive at the most accurate results. The surface of the tin canister A, exposed to the reflector, was variously coated and filled with hot water; but instead of watching the rate of cooling, as in the experiment with the cylindrical vessels, the effect upon the thermometer was observed. The differential thermometer answers admirably for this purpose, as from its construction it is not affected by the temperature of the medium in which it is placed, whereas the slightest inequality of the temperature of the bulbs is at once indicated.

In conducting demonstrative experiments, two reflectors are also sometimes used. These are arranged so as to stand exactly




opposite to each other with their principal axis in the same line, and the property of the parabolic form of reflector being that rays of heat or light, emanating from the focus *a* of one mirror, are reflected in parallel lines, and falling thus upon the other reflector, are again collected in its focus *b*. By this arrangement, the degrees of heat, radiated from different bodies placed in the focus of one reflector, can be estimated by placing the bulb of a thermometer in the focus of the other. For instance, a hot ball *a*, placed in the focus of one reflector, will considerably affect the thermometer placed in the focus of the other. To prove that the effect is not produced by the mere proximity of the heated ball to the thermometer, independent of actual reflection, it is only necessary to remove the reflector having the thermometer in its focus, or to cover it with a sheet of pasteboard or the like: the thermometer will immediately indicate the absence of the quantity of heat it before received, by the liquid ascending speedily in the stem, notwithstanding that the source of heat is as near the bulb as before. The same diminution of heat will likewise be indicated by the thermometer, if it be removed from the focus of the reflector and placed nearer the heated body; and indeed there is no other arrangement of the apparatus than that represented, in which the instrument is affected in any remarkable degree.

Sir H. Davy's method of arranging the reflectors vertically, has its advantages when the experiments are to be performed in a lecture-room, and when very striking effects are wished to be produced. The upper reflector is, in this case, suspended from the cross-arm of a frame of 12 or 15 feet in height, or from the ceiling of the room, if convenient, and the lower one may be placed on the floor. In the focus of the upper reflector is placed a little iron-wire cage, filled with burning charcoal. All the heat that reaches the upper reflector is, of course, concentrated in the focus of the under one, and will be found sufficient instantly to inflame phosphorus, explode fulminating silver, a mixture of chlorate of potash, and sulphuret of antimony, and gunpowder. In making these experiments, however, the material to be inflamed should be laid on a bit of paper. (The reflectors are here placed closely together to save room.)



The old experiments on the supposed radiation of cold may be also exhibited to advantage with an apparatus of this sort. If instead of the wire cage and burning charcoal, a mass of ice, sprinkled over with salt, be substituted, a thermometer placed in the focus of the lower reflector will sink rapidly, thereby indicating, according to the interpretation of the Florentine academicians, a radiation of *cold*. Even a small quantity of water may be frozen, with good management, if the temperature of the room be not very high (not above 60° or so.)

This experiment, upon which was built the hypothesis that cold is really a matter *sui generis*, and not a mere absence of heat, as is now the general opinion, is readily explained by referring to the process which causes the rise of the thermometer when a hot body is placed before the reflector. In this case the thermometer is really the hot body: and radiating its heat upon the nearest reflector, the rays are instantly projected upon the second, and collected in the focus, where they are absorbed by the ice. With regard to heat, the thermometer may be conceived as if placed in a vacuum: it receives no adequate return for the heat it radiates, and, as a matter of course, its temperature falls, and the more rapidly the higher its temperature above the ice.* The chilly sensation experienced when standing before a mass of ice, when warm, is explained in the same way: our body radiates its heat, and the ice absorbs it.

To examine the radiating and reflecting powers of different substances by this apparatus, it is not necessary to employ radiators and reflectors actually composed of the materials. These powers depend, as already stated, upon the nature of the surface, and can therefore be determined by producing merely a mechanical alteration of surface upon the radiator and reflector. Thus, the radiating power is conveniently exhibited by filling the cubical tin vessel, before referred to, with boiling water, and attaching thin layers of the substances to be examined, to its sides; and the reflecting power is similarly ascertained by modifying the surface of the reflector.

When one of the plane surfaces of the tin vessel is highly polished, and another is smoked, their radiating powers are found to be as 12 to 100. These are the lowest and highest degrees of radiating power, and all other substances have radiating powers varying within these extremes. The following table exhibits some of the relations among bodies in respect to this power; and, it will be remembered, that radiating and absorbing powers of the same body are co-equal, and are therefore expressed by the same numbers.

| | | | |
|---|---|---|---|
| Lampblack or soot, . | 100 | Plumbago, . . . . | 75 |
| Water (by estimate), . | 100 | Tarnished lead, . . | 45 |
| Writing-paper, . . | 98 | Clean lead, . . . | 19 |
| Sealing-wax, . . | 95 | Polished iron, . . | 15 |
| Crown-glass, . . | 90 | Tin-plate, Gold, Silver, Copper, } polished, . | 12 |
| China-ink, . . | 88 | | |
| Ice (by estimate), . . | 85 | | |
| Red-lead, Isinglass, } . . | 80 | | |

From this table it appears that the radiating power is quite independent of the colour of the body, and that, in all cases, bright metallic surfaces radiate least. When a metallic surface

* We are aware that objections might be raised to this explanation which it would not be easy to meet, yet we are satisfied that it is correct.

is allowed to tarnish, its radiating power is greatly increased: the radiating power of lead is raised from 19 to 45 by this means. It would appear, also, that a very smooth surface may radiate well, although it is generally found that the radiating power of a metal is augmented by roughening its surface. For instance, when a number of lines are scratched in one direction upon a bright metal, its power of radiation is increased; and it is still further augmented by drawing the same number of lines so as to cross the others at right angles, as if the radiating power depended upon the number of points produced. Some recent experiments, indeed, render it highly probable that it is not the degree of polish of the surface which determines the radiating power, so much as the closeness and density of what may be called the *radiating surface.* That this is at a sensible depth beneath the mathematical surface, is inferred from the fact, that when a polished metallic surface, as one of the bright faces of the cubical tin vessel before mentioned, is covered with successive layers of varnish, its radiating power is continually increased up to a certain thickness, beyond which no increase is observable. But if the radiating surface and the mathematical surface of the body were the same, the full increase of radiating power would be obtained by one layer of varnish, which is not the fact. We also find that bodies which are highly elastic, as ivory; and very hard, as agate, radiate in the same degree, whether their surfaces be rough or smooth, because their densities remain unaltered. But in the process of polishing a metallic plate, especially if it be rolled, the surface is very much compressed, and, in this state. radiates in the lowest possible degree: by rubbing with sand-paper, the dense film of compressed metal is removed, and the softer material underneath radiates with nearly double the power. If a plate of silver be cast without being subjected to any pressure, the surface, although perfectly bright, radiates with a power of 22; but if it be dimmed, by rubbing with sand-paper, the compression, though so slight, diminishes the radiating power to 12.* Melloni formed two silver vessels, one of hammered plate, and the other of cast and slowly cooled metal; one side of each was highly polished, and the other scratched with emery-paper in one direction only: on filling them with hot water, he found the following results:—

| | |
|---|---|
| Hammered metal polished = 10° | Cast metal polished = 13°.7 |
| Ditto scratched = 18° | Ditto scratched = 11°.3 |

The polished surface, therefore, of the cast metal radiated much better than that of the forged, showing the superiority of inferior density; but with the scratched surfaces, the radiating power is greater in the hammered or denser metal.

The same kind of apparatus which we have described, with a very slight modification, may be employed to determine the reflecting power of bodies; but the results in the following table were found by Buff, by a method more exact. Of 100 rays incident at an angle of 60 degrees from the perpendicular, there are reflected by

| | |
|---|---|
| Polished gold, | 76 rays. |
| —— silver, | 62 |
| —— brass, | 62 |
| Brass without polish, | 52 |
| Polished brass varnished, | 41 |
| Glass plate blackened on the back, | 12 |
| Looking-glass, | 20 |
| Metal plate blackened, | 6 |

The laws of the radiation of heat admit of many practical applications; some of which are in direct opposition to commonly received notions. Those bodies which radiate least cool slowest; and, consequently, if it be required to retard, as much as possible, the cooling of a hot liquid, for instance, it ought to be enclosed in a vessel with a bright metallic surface. This gives a reason for keeping the metallic vessels and covers for the table as bright as possible. On the other hand, if the object be to cool a liquid quickly, the surface of the containing vessel should be painted, or tarnished, or covered with a *thin* layer of some soft unmetallic coating. Steam, water, and air pipes, for warming houses, should be highly polished in those parts where the heat is not required to be communicated, and when they arrive at the localities where it is wanted, they ought to be painted with lamp-black, whitelead, or the like, to promote their radiating power. Culinary implements should be blackened, and not polished on those parts which are to receive heat. They ought not, however, to be thickly coated with soot: this, although the best absorber of heat known, is also very nearly the worst conductor; and, it must be observed, that radiation depends simply upon surface, whereas conduction is dependent upon the mass of the body. It may, indeed, be observed generally, that the best conductors are the worst radiators, and *vice versâ;* and that good conductors, consequently, present also bad receiving surfaces. A limit is, therefore, put to the gain and loss of caloric by radiation, by the opposite ranges of these powers. If a tin vessel, containing hot water, be wrapped round with a single fold of thin flannel, or the like, closely adhering to the surface, the cooling will be hastened, because the flannel is a better radiator than tin; but if several folds of the flannel be wrapped loosely round the vessel, the increased radiating power will be more than counterbalanced by the greater difficulty which the enclosed heat would have in being conducted outwards through so great a thickness of spongy, bad conducting material. The same remark applies with equal force to the reception of heat, as is shown in the facility or tardiness of the boiling of a kettle, according as it is thinly or thickly coated with soot.

These facts, also, prove the necessity there is for thick clothing in both extremes of temperature. But it is to be observed, that, although *colour* does not appear to have any influence upon terrestrial radiant heat—the heat which is radiated from terrestrial fires, and other hot bodies—the case is very different as respects the heat which comes to us with the sun's light. A body receives and absorbs the same quantity of heat when exposed before a fire, whether it be painted black or white; but when exposed to the solar radiation for a given time, the temperature will be elevated in proportion to the intensity of its colour. This is well illustrated by exposing pieces of cloth of different colours to the sunshine upon the surface of snow; that which is black will, by absorbing most heat, melt the snow away from under it, and sink deepest. White will sink least, and the others in the order of their depth of colour. We are, therefore, correct in using dark coloured clothes in winter, and light colours in summer.

These facts would seem to prove that there is an essential difference between solar and terrestrial radiant heat; but this is, probably, rather apparent than real. In the solar beam, the light and heat come to us together, and when they fall upon a dark surface, they are absorbed together. The beam passes through a thin plate of glass without any appreciable loss in intensity of either light or heat; but if the same experiment be tried with the rays from a lamp, or candle, or fire, it will be observed, that the light passes through the glass, but that part of the heat is stopped in the progress: in the case of the sun's rays, the glass is scarcely heated; in the case of radiation from a fire, the glass soon becomes hot.†

We are now in a condition to advert to the circumstances attending the establishment and continuation of an equilibrium of temperature among bodies of unequal temperatures, when placed in the vicinity of each other. When bodies are placed in contact, a transfer of heat takes place from the hotter to the colder body by conduction as already explained: both, however, soon acquire the common temperature of the atmosphere and of surrounding bodies. This is effected in part by carrying currents of air, withdrawing successively portions of heat from the bodies and diffusing it in the atmosphere; but the chief power which appears to be concerned in the process is radiation, and it may be observed that radiation goes on in a vacuum as well as in air or gases. The whole process is indeed explained at once by the beautiful and simple theory proposed by Prevost of Geneva. The principle is this:—all bodies in nature are in a continual state of interchange of heat; no matter how hot or how cold a body may be, it is continually giving out radiant heat to other bodies, and receiving in exchange and absorbing the heat it receives from them. But the quantity of heat thus radiated depends on the temperature of the body; the higher this is, the greater the quantity of heat thrown off, and the lower the temperature, the less is the heat radiated in a given time. Thus, a hot ball suspended among balls of an inferior temperature, will receive radiant heat from all the balls around it, but the quantity will be small in proportion to the heat which itself radiates: its temperature will therefore fall, and the temperature of the other balls will be elevated, on the principle "that the temperature of

* Kane's Elements of Chemistry.

† We shall have occasion to return to this subject.

a body falls when it radiates more than it absorbs, and rises when it absorbs more than it radiates." The temperature is therefore constantly tending to an equalization, and the mutual radiation and absorption of heat by the bodies maintains it when once established. In the same way we see that every body whose temperature we may alter by artificial means, as by placing it in a furnace or in a freezing mixture, begins to cool, or to become less cold by its excessive radiation or absorption, when exposed to the common temperature of the atmosphere.

This principle of the uniformity of temperature being sustained by equal radiation and absorption, furnishes us with the solution of many interesting natural phenomena. The production of *dew* and *frost* are among the number. The earth, as a mass, is a good radiator; and in the absence of the sun, the temperature of its surface would always be considerably lowered, were it not for the canopy of clouds which very generally float around it, and radiate in return. But when the sky is clear, all the heat radiated by the earth escapes into the planetary space, and the temperature of the surface, if the air be calm, is found from ten to twenty degrees lower than the atmosphere. The stratum of air in contact with the ground is in consequence cooled by contact, and a portion of its watery vapour, which at the ordinary temperature it holds in its elastic form, is condensed and deposited as liquid water, and this we call *dew*. If the temperature be otherwise low, and the night very clear, the drops of dew may be frozen at the moment of their deposition, and form *hoar-frost*.

The truth of this explanation is evinced by various circumstances, but chiefly by the fact, that it is only on calm star-lit nights, and on the surfaces of good radiators, that dew or hoar frost is deposited. When the sky is overcast with clouds, the heat which is radiated from the earth is returned to it again, and the temperature is thus kept up. The slightest screen stretched over a piece of ground in this way, prevents its radiant heat from escaping into space, and no dew is deposited on the spot. This fact is well known to gardeners, who availed themselves of it to protect their tender plants from frost, long before the laws of the radiation of heat were explained. That the dew and frost are deposited in consequence of radiation, is obvious from the fact,—the quantity deposited upon bodies is always in proportion to their radiating powers. For instance, if a plate of polished metal be laid on the middle of a piece of woollen cloth, and exposed to the air in a night favourable to the deposition of dew, scarcely a trace of dew will be observed upon the metal in the morning, while abundance will be found upon the cloth. This explains why stones, gravel-walks, and smooth leaved plants have little dew or frost upon them, when grass and rough foliage (which are excellent radiators) are found wet or white in the spring and autumn mornings.

The same explanation comprehends the process for making ice, followed by the native Hindoos, near Calcutta; where the temperature of the air very rarely falls so low as 40° even in the coldest nights. But the sky is cloudless, and a powerful radiation goes on from the surface of the ground when the sun is down. Taking advantage of this, water contained in shallow pans is imbedded in straw; and if circumstances are favourable, it is found, after the night's exposure, sheeted over with ice. It has been said that this is owing to evaporation; but it is obviously a case of radiation. This is demonstrated by two circumstances: the process succeeds best when the pans are placed in shallow trenches dug in the ground,—an arrangement which retards evaporation; and no ice forms when the night is windy, although evaporation is then greatest.

## MATHEMATICS.

### CHAPTER IV.

#### DIVISION OF WHOLE NUMBERS.

1. Division, as stated before (chap. ii. art. 6), is a concise method of performing many subtractions of the same number, and is to be regarded as an operation exactly the inverse of multiplication. In this last, we have seen that the product of two numbers consists of one of these numbers repeated as many times as the other contains 1, that is to say, the product contains one of the factors the number of times expressed by the other. If therefore we have a product given and one of the factors, the other factor will be found by reversing the process by which the product was formed—that is, by subtracting the known factor continually from the product until nothing is left. Thus supposing it is required to find how often 161 contains 23, or that the following question is asked:—There is a heap containing 161 pebbles, how many lesser heaps, containing each 23 pebbles, can be formed out of it? The simplest mode of proceeding is obviously, to take 23 from the heap, and put them into a heap by themselves; then to take another 23 from the heap, and place them in another heap by themselves; and so on until the heap is exhausted. After *seven* subtractions, we find that nothing is left, and therefore we conclude that 161 contains 23 that number of times. Here 161 is called the *dividend;* 23 is the *divisor*, and 7 is the *quotient;* and the process by which a quotient is found is *division*.

$$\begin{array}{rr} 161 & \\ 23 & 1 \\ \hline 138 & \\ 23 & 1 \\ \hline 115 & \\ 23 & 1 \\ \hline 92 & \\ 23 & 1 \\ \hline 69 & \\ 23 & 1 \\ \hline 46 & \\ 23 & 1 \\ \hline 23 & \\ 23 & 1 \\ \hline 0 & \end{array}$$

2. When the dividend contains the divisor a great number of times, it is hardly practicable to employ continued subtraction to obtain the quotient: and accordingly we have recourse to methods of abbreviation analogous to those given for multiplication. But before proceeding to these, it is necessary to observe that when the divisor is not greater than 12, and the dividend not more than 12 times as great as the divisor, the quotient must be contained among the products of the table given in chap. iii. art. 1. For example, if it be inquired how often 56 contains 8; on consulting the table, we find 8 in the column of multipliers, and 56 in the same horizontal line and under 7; the other factor 7, expresses therefore the number of times which 56 contains 8. But we observe that this table does not contain among its products all numbers between 4 and 144, although it contains all the factors between 2 and 12; there must therefore be numbers within that range, which cannot be divided exactly by any of these factors. For example, we find in the table 42 and 44, but not 43; this number is therefore not divisible exactly by any factor given in the table; but further we observe that 42, although it occurs twice, is not found among the products of 8, and we therefore conclude that it is not divisible exactly by 8. This may be proved by following the process in art. 1., by which it will appear that having subtracted 8 five times from 42, there remains 2: we then say that 42 contains 8 five times and 2 *over*, or that 42 divided by 8 gives a *quotient* 5 and a *remainder* 2. This is exactly what the table informs us; for as 42 is between 40 and 48, we observe that the highest product of 8 which it can contain is 40, the factors of which are 8 and 5, and the difference between 42 and 40 is the remainder 2. If we use the signs, the expression is $42 = 8 \times 5 + 2$.

3. The sign commonly used to denote arithmetical division is sometimes $\div$, and at other times :, but by far the neatest and most convenient way of expressing division is to write the dividend above, and the divisor beneath a small horizontal line. These modes are exemplified in denoting the division of 8 by 4 as follows:—

$$8 \div 4 = 2 \qquad 8 : 4 = 2 \qquad \frac{8}{4} = 2$$

For convenience during the operation, we sometimes write them as follows:—

When the divisor is small, $\begin{array}{r} 4\underline{)8} \\ 2 \end{array}$

When the divisor is large, 4) 8 (2

4. In dividing one number by another, we may break up the dividend, and divide each of its parts by the divisor; and then add the results together. Thus it is plain, that 144 contains 8 just as often as all its parts together. Now 144 is made up of 80, 40 and 24, and of these,

80 contains 8, 10 times
40 contains 8, 5 times
24 contains 8, 3 times

Therefore $80+40+24$ contains 8, $10+5+3$ times,
or 144 contains 8, 18 times.

But again, 144 is made up of 100, 40 and 4;

and 100 contains 8, 12 times and 4 over,
40 contains 8, 5 times and 0 over,
4 contains 8, 0 times* and 4 over.

Therefore $100+40+4$ contains 8, $12+5+0$ times and $4+0+4$ over, or 144 contains 8, 17 times and 8 over. But 8 contains 8, 1 time, and therefore 144 contains 17 eights and 1 eight or 18 eights.

The proof that $144 \div 8 = 18$ is that $18 \times 8 = 144$, or that the divisor and quotient multiplied together produce the dividend.

5. In applying this principle to other cases of division, it is not necessary actually to separate the dividend into parts before commencing the process: the same may be done more concisely during the working. Te illustrate this, let it be required to divide 11115 by 9. The question is to find a number which multiplied by 9 will give 11115; but that number will be ascertained by finding out how often 9 can be subtracted from 11115. We might therefore proceed to subtract 9 continually, as we did 23 in a former example, until the dividend is exhausted; but it will obviously not affect the result to subtract as many *nines* at a time as we may find convenient, taking care to mark at each step how many are taken away. Now we at once see that 11115 is greater than 1000 times 9; we therefore take away 9000 at once; the quantity 2115 which remains is greater than 200 times 9 (for $9 \times 200 = 1800$, whereas the remainder has 21 hundreds); we therefore take away 1800 leaving a remainder of 315; this remainder again is greater than 30 times $9 = 270$; this number being subtracted, there remains 45 which we know to be just 5 times 9. Therefore 11115 contains 9, $1000+200+30+5$ times, that is 1235 times. The process is shown on the margin above.

$$\begin{array}{rl} 11115 & \\ 9000 & 1000 \text{ times } 9 \\ \hline 2115 & \\ 1800 & 200 \text{ times } 9 \\ \hline 315 & \\ 270 & 30 \text{ times } 9 \\ \hline 45 & \\ 45 & 5 \text{ times } 9 \\ \hline 0 & \end{array}$$

In this operation it will be observed that we really separated the dividend 11115 into parts in finding that

$$11115 = 9000 + 1800 + 270 + 45$$

and had these parts been known to us previous to commencing the operation, we might have proceeded with the division as on the margin.

$$\frac{9000}{9} = 1000 \qquad \frac{1800}{9} = 200 \qquad \frac{270}{9} = 30 \qquad \frac{45}{9} = 5$$

$$\text{Therefore } \frac{11115}{9} = 1235$$

6. From these illustrations it is obvious that the only difficulty which occurs, is in finding out how many times we may subtract the divisor at each step, and this is in a great measure removed by considerations of the following kind:—

21 contains 7, 3 times: therefore
10 times 21 or 210 contains 7, 30 times,
100 times 21 or 2100 contains 7, 300 times,
1000 times 21 or 21000 contains 7, 3000 times,

15 contains 5 more than 2 times; therefore
150 contains 5 more than 20 times,
1500 contains 5 more than 200 times,
15000 contains 5 more than 2000 times;

| | | | | | | |
|---|---|---|---|---|---|---|
| 18 | contains | 7 | more than | 2 | times, and less than | 3 times, |
| 180 | | 7 | | 20 | | 30 times, |
| 1800 | | 7 | | 200 | | 300 times, |
| 18000 | | 7 | | 2000 | | 3000 times, |
| 180000 | | 7 | | 20000 | | 30000 times. |

To illustrate these principles, let it be required to divide 40761 by 7, that is to find $\frac{40761}{7} = ?$

Here the first figure, 4, of the dividend is less than 7; the quotient sought is therefore less than 10000, for $10000 \times 7$ gives 70000, which exceeds 40761. But we observe that 40, the first and second figures together, contains 7 more than 5 times, and less than 6 times; therefore, 40,000 contains 7 more than 5000 times, and less than 6000 times. But 40761 also contains 7 more than 5000 times, for 40761 is greater than 40000; it also contains 7 less than 6000 times, because 6000 times 7 is 42000, a greater number than 40761. We may therefore subtract 5000 times $7 = 35000$ from 40761, which leaves a remainder of 5761. The quotient sought is therefore $5000 + \frac{5761}{7}$. It remains now to find how many times 5761 contains 7. Proceeding as before, we observe that 5 does not contain 7, but that 57 does contain it more than 8 times, and less than 9 times; therefore, 5700 contains it more than 800 times, and less than 900 times; as does 5761; subtracting the 800 times 7, or 5600, there remains 161. The quotient is therefore $5000 + 800 + \frac{161}{7}$. Now, 16 contains 7 more than 2 times and less than three times; therefore, 160 contains 7 more than 20 times, and less than 30 times; as does also 161; subtracting then 20 times 7, or 140, there remains 21. Now, 21 contains 7 just 3 times; and this being subtracted, the dividend is exhausted. We therefore conclude that

$$\begin{array}{rl} 40761 & \\ 35000 = & 5000 \text{ times } 7 \\ \hline 5761 & \\ 5600 = & 800 \text{ times } 7 \\ \hline 161 & \\ 140 = & 20 \text{ times } 7 \\ \hline 21 & \\ 21 = & 3 \text{ times } 7 \\ \hline 0 & \\ \hline 40761 = & 5823 \text{ times } 7 \end{array}$$

$$\frac{40761}{7} = 5000 + 800 + 20 + 3 = 5823.$$

The following examples may be gone over in the same manner:—

$$\frac{1656}{3} = 552 \qquad \frac{8765}{5} = 1753 \qquad \frac{97587}{7} = 13941$$

7. The same method illustrated above is applicable however great is the divisor. One other example will make this plain: let it be the following—Divide 4298689 by 576.

We here observe, that it takes the four figures on the left of the dividend, namely, 4298, to make a number which is greater than 576, the divisor: the dividend is therefore separated into 4298000 and 689. Now, 4298 is found to contain 576 more than 7 times, and less than 8 times; therefore 4298000 contains it more than 7000 times, and less than 8000 times; and subtracting $576 \times 7000$ from the dividend, the remainder is 266689. The four figures, namely 2666, on the left of this remainder, contain 576 more than 4 times, and less than 5 times, therefore the whole remainder contains it more than 400 times, and less than 500 times; and $576 \times 400$ being subtracted, there arises the new remainder. With this the same operation is repeated until it appears that the quotient is

$$\begin{array}{rl} 4298689 & \\ 4032000 = & 7000 \text{ times } 576 \\ \hline 266689 & \\ 230400 = & 400 \text{ times } 576 \\ \hline 36289 & \\ 34560 = & 60 \text{ times } 576 \\ \hline 1729 & \\ 1728 = & 3 \text{ times } 576 \\ \hline 1 & \textit{remainder.} \end{array}$$

$$7000 + 400 + 60 + 3 \text{ and } 1 \text{ over.}$$

8. It will be observed in examining the foregoing examples, 1st. That it is unnecessary to write the ciphers which are placed on the right of each subtrahend, provided we take care to keep the significant figures in their proper places without them. 2d. That it is unnecessary to put down those figures of the dividend which fall over ciphers as they do not begin to be of use in forming the quotient until significant figures fall under them; and 3d. That the figures of the quotient might be written in succession in the usual way. The last example is shown in this abridged form at the side, and it is particularly to be remarked: 1st.

Divisor. Dividend. Quotient.

$$\begin{array}{r} 576)4298689(7463 \\ 4032 \\ \hline 2666 \\ 2304 \\ \hline 3628 \\ 3456 \\ \hline 1729 \\ 1728 \\ \hline 1 \end{array}$$

* We use this form of expression for convenience. We ought to say that 4 *does not contain* 8, but the expression 0 times is equally intelligible, and is therefore preferable on the score of uniformity.

*That one figure of the given dividend appears on the right of every partial dividend. 2d. That for every figure of the dividend not employed in the first partial division, there is a quotient figure of the same order.*

9. From the nature of the numeration scale, it is obvious that no partial quotient can exceed 9, which is the highest number of only one figure: should a partial product come out 10 or more, there is an error in the preceding step.

10. From the foregoing principles, the following rule for division is deduced:—

I. *Write the divisor and dividend in one line, and place reversed parentheses on each side of the dividend.*

II. *Cut off from the left of the dividend, the smallest number of figures which make a number as great or greater than the divisor; find what number of times the divisor is contained in these, and write the figure which results as the first figure of the quotient.*

III. *Multiply the divisor by the quotient figure, and subtract the product from the number which was cut off as a partial dividend, from the left of the given dividend. (If the product cannot be subtracted, that is, if it is greater than the part of the dividend cut off, the figure placed in the quotient is too great, and a less figure must be taken. On the other hand, if after the subtraction, the remainder be greater than the divisor, the quotient figure has been taken too small, and a greater one must be taken.)*

IV. *On the right of the remainder place the figure of the dividend which comes next after those at first taken in II.: find how often this number contains the divisor, and place the resulting figure on the right of the first figure of the quotient: multiply the divisor by it, and subtract the product which results from the partial dividend. (Should it happen at any time that the remainder, increased by the figure of the dividend taken down, is less than the divisor, a 0 must be placed in the quotient, and another figure of the dividend brought down; and this must be repeated, if necessary, until the augmented remainder is capable of containing the divisor, or the figures of the dividend are exhausted.)*

V. *Proceed with all subsequent partial dividends as directed in IV., continuing the process till all the figures of the dividend are brought down.*

The following example illustrates this rule:—

```
Divisor. Dividend. Quotient.
  251 )577556( 2301
       502
       ---
        755
        753
        ---
          256
          251
          ---
Remainder   5

Proof.
  2301 Quotient.
   251 Divisor.
  ----
  2301
 11505
 4602
       5 Remainder.
 ------
 577556 Dividend.
```

Here we take the first three figures on the left of the dividend, as the first partial dividend, and dividing by the divisor, we write in the quotient the number 2, resulting from the division, and multiply the divisor by this number. We write the product 502 under the partial dividend 577. The subtraction being performed, we bring down the 5 hundreds of the dividend, and annex the figure to 75, the remainder. We divide this new partial dividend by the divisor, and obtain 3 as the second figure of the quotient; we multiply the divisor by this number, and subtract the product 753. To the remainder, 2, we annex 5, the tens' figure of the dividend, making a partial dividend 25. But as this does not contain the divisor, (or, as we say for the sake of uniformity of expression, as 25 *contains* 251, 0 *times*,) we write 0 for the next figure of the quotient, and bring down 6, the units' figure of the dividend, making the partial dividend 256. This containing the divisor *once*, we therefore write 1 in the units' place of the quotient, and subtract the divisor, that is, $251 \times 1 = 251$, from the partial dividend 256; this gives a remainder 5.

$$\text{Therefore } 577556 = 251 \times 2301 + 5.$$

When the divisor contains several figures, as in the foregoing example, some difficulty may be felt in discovering how often it is contained in the partial dividend. Although nothing but practice can enable us to do this with facility—for with every one it is a sort of guess-work—yet the difficulty is not in reality so great as it in general appears to the beginner. We take the following example to show how it is accomplished—Divide 423405 by 485.

```
485 )423405( 873
     3880
     ----
      3540
      3395
      ----
       1455
       1455
       ----
          0
```

Taking the four figures on the left of the dividend to form a number capable of containing the divisor, we do not see immediately how often 4234 may contain 485. To aid us in guessing, we observe that 485 is between 400 and 500, and that if it were either the one or the other of these numbers, the question would be reduced to finding how often 4 or 5 is contained in 42. The reason is, that 4 or 5 being contained in 42 as often as 400 or 500 is in 4200, and this last differs little from 4234. We see at once, then, that our quotient figure cannot be greater than 10, nor less than 8: it cannot be so great as 10; for on that supposition, the three figures on the left of the dividend would contain the divisor *once*, which they do not. It only remains, then, to try whether 9 or 8, employed as a multiplier of 485, yields a product which can be subtracted from 4234, and we find that it is 8; 8, therefore, is the first figure of the quotient. When $485 \times 8 = 3880$ is subtracted, and the next figure (0) of the dividend annexed, we find the second partial dividend to be 3540. Reasoning upon our divisor as before, we observe that the next quotient figure cannot be greater than 8, nor less than 7; but as 485 is nearer to 500 than to 400, we try 7, which results from a division of 35 by 7; the supposition turns out to be correct; for $485 \times 7 = 3395$, and this subtracted from 3540, leaves 145, which is less than the divisor. By annexing 5 to 145, we get 1455, our third partial dividend, and as 1455 approaches to 15,00, and 485 to 5,00, we try 3 for our next quotient figure, and find that $485 \times 3 = 1455$.

It would now be highly advantageous to repeat the foregoing three articles, with the following examples:—

$$\frac{3978}{17} = 234 \qquad \frac{6331}{21} = 301 \qquad \frac{197028}{234} = 842$$

Prove that $224091 = 4309 \times 52 + 23$.

Also, that $\dfrac{224091 - 23}{2} = 4309 \times 26$.

Is $215414 = 1781 \times 121 + 13$?

# ANATOMY AND PHYSIOLOGY.

## CHAPTER IV.

### THE MUSCLES AND MUSCULAR ACTION.

There are about 450 muscles in the human subject, 225 on each side, with a small numerical difference in the male and female. In describing the muscles, I will give each its anatomical name, for it is not possible to do justice to the subject without it. The description will, in general, not be so minute as to fatigue the reader's mind, and the whole will be separated into natural divisions. The skin is supposed to be dissected from the accompanying figure exhibiting the principal muscles of the face.

There are four muscles in the face; 1st, The occipito frontalis covers the upper part of the cranium, or skull, corrugates the hairy scalp, and wrinkles the forehead when we express passion. 2d, Corrugator supercilii forms part of the eyebrow, and wrinkles it when we frown. 3d, Orbicularis oculi covers and surrounds the eyelids, presses the eyeball firmly into the socket, and squeezes the tears from the lachrymal gland. 4th, Levator palpebræ superioris spreads over the upper eyelid, and forms it. When elevated the eye is open, when depressed it is shut, and when paralyzed it is closed.

There are twelve muscles in the nose and mouth. 1st. The levator labii superioris and alæ nasi, extends along the nostrils, raises the upper lip, and widens the nostrils, especially

when we are enraged, or spasmodically cough, as we do in asthma. 2d. Levator labii superioris proprius forms part of the

cheek and upper lip, and pulls the upper lip and septum of the nose directly upwards. 3d. Levator anguli oris forms part of the angle of the mouth, and raises it upward. 4th. Zygomaticus major forms part of the cheek, the corner and circle of the mouth, and depresses the lip. 5th. Zygomaticus minor has its origin, insertion, and action, nearly the same as the zygomaticus major. These zygomatic muscles mark the face with the line (which extends so visibly in some individuals,) from the cheek-bone to the corner of the mouth, and pull the angles of the mouth upward, when we laugh, rage, or grin. In negroes, there are frequently three zygomatic muscles, but only two in Europeans. 6th. Buccinator assists in forming the walls of the cheek, flattens the cheek, assists us in swallowing liquids, and in turning the morsel we are chewing in our mouths, and likewise prevents it getting betwixt our teeth; and when we blow wind instruments, these muscles dilate like a bag, and, contracting upon the wind in the mouth, expel it, and swell the notes. 7th. Depressor anguli oris forms part of the flesh of the lower jaw and corner of the mouth, gives form to the chin and mouth, and expresses laughing, smiling, and other cheerful passions. It also assists in pulling the corner of the mouth downward, especially when we express the malignant passions of hatred, contempt, and revenge. 8th. Depressor labii inferioris lies on the sides of the chin, and pulls the lip downward. 9th. Orbicularis oris lies in the red part of the lips, surrounds the mouth, contracts and shuts it. 10th. Depressor labii superioris, and alæ nasi, arises from the socket of the fore teeth, goes into the root of the nostril, and pulls the nose and upper lip downward. 11th. Constrictor nasi lies on the side of the nose, goes to its very point, and compresses it. 12th. Levator menti arises at the root of the incisor teeth, spreads on the centre of the chin, contracts it, and forms the dimple.

The muscles of the nose and mouth are not only useful to express our passions, but also assist us in performing the more important functions of breathing, speaking, chewing, swallowing, &c., and opening and shutting the mouth. Partial paralysis of these muscles induces a frightful distortion of the countenance. If one side of the face only is paralyzed, the palsied muscles of the affected side cease to act, and the sound ones on the healthy side still exerting their usual vigour, pull the palsied muscles toward the unparalyzed side, and distort the face.

In some individuals, when the facial muscles and passions are at rest, their countenances indicate nothing but muscular harmony; but whenever they smile, laugh, grin, or exhibit anger, their mouths and faces are instantly drawn to one side, and remain in that state till the paroxysm is over. This is caused by a chronic paralysis of some of the muscles on one side of the face having reduced their power, and made it unequal to their antagonists of the opposite side.

On the external ear there are eight muscles. 1st. Superior auris, expands on the fascia of the temporal muscle behind the ear, terminates in the antihelix, (or inner ring of the ear,) posteriorly, and lifts the ear upward. 2d. Anterior auris, arises from the zigoma, (or arch of the cheek,) and passes into the helix, or outward ring of the ear. 3d. Posterior auris, arises from the mastoid process of the temporal bone on the side of the head, and is inserted into the back part of the concha, or shell of the ear. 4th. Helicis major, lies on the sharp point of the helix, or outward ring of the ear, and is inserted a little above the tragus, or the outward cartilage, or grisly substance of the ear. 5th. Helicis minor, lies a little lower on the ear than the helicis major. 6th. Tragicus, and 7th. Antitragicus, lie contiguous to each other, on the ear, anteriorly, almost in juxtaposition. 8th. Transversus auris, runs on the back part of the ear, from the shell to the inner ring.

There are still a few smaller muscles, which also belong to the ear, move and give tension to its external cartilages, and prepare it for receiving and propagating the vibrations of air and sound along its tube. These I will not here describe nor enumerate, because they are too minute for the general student to perceive, unless by actual dissection.

The muscles of the eyeball are six in number. 1st. Rectus superior, lifts the eye directly upward, and expresses its haughtiness and pride. 2d. Rectus inferior, pulls the eye downward, expressing modesty and humility. 3d. Rectus internus, carries the eye inward, towards the nose. 4th. Rectus externus, turns the eye away, expressing anger and scorn. 5th. Obliquus superior, (like the recti superior and inferior,) arises in the bottom of the eye, above, towards the inner side, directing its long smooth tendon to the internal angle of the eye, and there it passes through a cartilaginous pulley, placed above the eye, and projecting farther than the most prominent part of the eyeball. The tendinous cord then returns at an acute angle, and bends its centre downward before it can touch the eyeball; it then returns backward in a direction opposite the recti muscles, slips under the body of the rectus superior, and spreads under it, and upon, or behind the middle of the eye, about half-way betwixt the insertion of the rectus superior and the entrance of the optic nerve into the eyeball. 6th. Obliquus inferior, is directly opposed to the obliquus superior in form, place, and office: it is a short, flat, broad muscle, arising from the orbitary process of the superior maxillary or cheekbone, near its union with the os unguis (or eyebone,) and is inserted and expanded on the eyeball, exactly opposite the insertion of the obliquus superior. These two last named muscles, (obliqui superior and inferior,) support the eyeball for the operation of the recti muscles; for when the oblique muscles act, and pull the eye forward, the recti muscles resist them, and the insertion of the oblique muscles at the middle of the eyeball becomes, at that instant, a fixed point or axis, round which the eyeball turns, under the operation of the recti muscles. The conjoined action of the oblique muscles brings the eyeball forward from the socket. The superior oblique muscle, acting alone, does not bring forward the eye, but rolls it so as to turn the pupil downward and towards the nose. The single action of the obliquus inferior is the reverse, for it returns the eye again upon its axis, and directs the pupil upward and outward.

But it may be necessary to enter a little more minutely into the mechanism and physiology of the recti muscles of the eye, collectively and individually, to make the reader more easily comprehend their harmony and usefulness, in making us accomplish a mechanically correct vision, and see objects as they are distinctly. The four recti muscles, superior, inferior, internus, and externus, arise by flat, small tendons, round the margin of the optic foramen, (or hole,) at the bottom of the socket, and are placed, one above, one below, and one on either side, and completely surround and adhere to the optic nerve; they then gradually expand upward, and with their fleshy bellies surround and cover the middle of the ball of the eye, and still expanding and extending upward, each at last terminates in a broad, flat, white tendon, covering all the fore part of the eyeball up to the

very circle of the lucid cornea, (or window of the eye,) and these very white and shining tendons anteriorly, form what is called the white of the eye. The rectus externus, is the muscle nearest the temple, and is a little longer than the rectus internus nearest the nose. The rectus superior, is above, the rectus inferior, below, and are both of equal length. The eye is thus entirely surrounded with its muscles, which turn and move it mechanically in all directions, either for looking accurately at small, large, near, and distant objects, or expressing the emotions and passions of the mind.

Strabismus, or squinting, is caused by one or more of the muscles of the eye being shortened or elongated; and by the derangement of their action, the pupil is consequently carried out of the proper axis of vision. It is cured by a very simple operation. The shortened or elongated muscle is cut down upon and divided by a skilful operator. The false position of the pupil is immediately rectified by the division of the diseased muscle, that induced obliquity by its irregular action. Inflammation is subsequently prevented, or removed, by proper applications. The divided muscle in healing shortens, or lengthens; and during the healing process, suits itself to the exigences of the case, and in a short time reunites. All the muscles of the eye now act in harmony, and the squinting is radically removed. No person need submit for any length of time to obliquity of vision, so long as he can be effectually cured by submitting to this simple, and not very dangerous operation. But like other surgical operations it is sometimes unsuccessful; and a case lately happened, in which, after the operation by a surgeon, the patient was rendered blind of the defective eye.

There are four muscles in the lower jaw. 1st. The temporal, arises from the flat side of the parietal bone at the side of the head, and the sphenoid and frontal bones in that hollow, behind the eye, where they meet to form the squamous suture; it also arises from the inner surface of that strong tendinous membrane, which is extended from the jugum, or yoke, to the semicircular ridge of the parietal bone, at the side of the head. The muscle is pyramidal, its rays converge towards the jugum, its tendon passes under it, and is inserted into the coronoid process of the lower jaw. It pulls the lower jaw firmly up, and when we bite, it swells on the flat part of the temple, so as to be felt outwardly. 2d. The masseter, a short, thick, fleshy muscle, which gives the visible rounding to the cheek, arises from the upper jawbone, and covers the branch of the lower jaw, quite down to its angle, where it is inserted. The parotid gland lies on its upper portion, and the duct of the gland, crossing the cheek, lies over the muscle. It pulls up the jaw, and when we bite, it is felt swelling on the back part of the cheek. 3d. Pterygoideus internus, arises from the internal flat pterygoid process of the sphenoid bone, and goes inwardly to the angle of the lower jaw. 4th. Pterygoideus externus, arises from the outside of the external plate of the pterygoid process of the sphenoid bone, and the adjoining part of the upper maxillary or cheekbone, and is inserted into the neck of the condyle of the lower jaw, and to the upright part of the bone and capsule of its joint. The lower jaw is chiefly moved by these four muscles. The temporal muscle acts on the coronoid process of the lower jawbone like a lever, and raises it. The masseter muscle acts before the temporal muscle on the angle of the lower jaw, and lifts it. The pterygoideus internus acting within the lower jawbone balances the action of the masseter on the outside. In biting, holding, and tearing our food with our teeth, these three muscles pull the lower jaw very forcibly upward. The fourth muscle, or pterygoideus externus, going from within, outward from its origin to its insertion, naturally pulls the lower jaw from side to side in chewing, and performs the motion of grinding the food.

There are two muscles that lie on the fore part of the neck and move the head. 1st. Platysma myoides, a very thin muscular expansion, spreading over the other muscles of the neck and throat, and extending upward on the lower part of the face and lower jaw. It supports the parts of the neck, compresses the veins, and, in difficult breathing, forces the blood down into the chest. It is more a muscle of respiration and circulation than of mental expression; yet in some of the most violent passions, it is very active and effective in their malignant exhibition. 2d. Mastoideus is the finest and most conspicuous muscle of the body, giving the fleshy roundness to the neck, and rising up when in action, it produces the most beautiful contour in the necks of men and women. It begins by a strong tendon from the triangular position of the sternum, or breast-bone, and from the sternal portion of the clavicle (or collar bone,) by a broad and fleshy origin, and is inserted into the mastoid angle of the temporal bone, at the side of the head. When the mastoid muscles act in unity on both sides of the head, they pull the head downward, and bring the chin in contact with the chest. When one only acts on one side of the head, it pulls the ear down to the shoulder, and by twisting the neck, throws the chin a little up to one side. This muscle is subject to the disease which sometimes produces a wry neck; and it requires a correct knowledge of anatomy, in some cases, to discover whether the distorted neck arises from disease or palsy of the mastoid muscle, or an affection of the spine.

Before describing any more of the muscles, I will briefly enumerate the bones and cartilages that form the basis of the throat and tongue, and are the centre of their motions. 1st. Os hyoides is a small bone (resembling the lower jawbone), that forms by its basis the root of the tongue, and is sometimes called the bone of the tongue. Its horns keep the gullet and windpipe extended, and it is the centre of the motions of the tongue and muscles of the throat. The trachea, (or windpipe,) conveys the air to the lungs. The larynx is the head (or figured part) of the air-tube which is formed like a flute, for the modulation of the voice, and is composed of several cartilages, or grisly rings, that it may stand firm and uncompressed; were it otherwise, the windpipe would be liable to collapse, and induce suffocation. It has five principal cartilages:—1st. The thyroid cartilage, makes that prominence on the middle of the throat called pomum Adami, or apple of Adam. Its two long horns at its upper corners rise like hooks above the line of the cartilage, and are joined to the horns of the os hyoides, or bone of the tongue. 2d. The cricoid cartilage lies next the thyroid, and below it; and on its back, or deeper part, internally, are seated two small cartilages, which, with their ligaments, form the opening of the windpipe, for the admission of air into the lungs. 3d. and 4th. The arytenoid cartilages are two in number, and seated within for protection of the thyroid cartilage, and are covered with the common membrane of the throat, which is thick and full of mucous glands; and betwixt these ligaments, the rima glottides, or chink, is formed for opening a passage into the tube of the trachea, or windpipe. The voice is in a considerable degree formed by the motion of these cartilages with their ligaments; and the action of their muscles is so exquisitely minute, that for every change of tone, and there are thousands of changes in the human voice, they move in a proportionally minute degree to effect it. 5th. The epiglottis is fixed to the thyroid cartilage, the bone and root of the tongue, and in action executes the part of a key to a wind instrument. It defends and shuts the rima glottides, or opening into the windpipe, especially when we swallow food or liquids, and by covering the opening, prevents the smallest morsel or drop from entering the windpipe; for a morsel passing into the windpipe would cause instant suffocation and death. The rareness of such accidents indicates its perfect mechanism and utility, and causes us to admire the infinite wisdom and skill of our almighty Creator and Preserver.

In my next essay I will proceed with the muscles.

## GEOLOGY.

### CHAPTER IV.

DESCRIPTION OF THE ELEMENTARY SUBSTANCES WHICH ENTER INTO THE COMPOSITION OF THE EARTH, AND THEIR MORE IMMEDIATE COMPOUNDS.

IV. *Metals.*

*Manganese* forms a constituent of many minerals. The black oxide is found native in great abundance. The native peroxide occurs crystallized and compact in Devonshire, Somersetshire, and in Aberdeenshire. The crystals often occur with the sulphate of barytes and are found radiated in rhomboidal dark-grey coloured prisms. Oxide of manganese occurs principally in primary and transition rocks in nodules or irregular masses, in veins

and in beds. Manganese is very widely disseminated, but its proportions are much less than iron.

*Iron* according to the calculation of De la Beche constitutes about 2 per cent, of the whole mineral crust of the earth. It occurs as an ingredient in mostly all mineral compounds. Native iron is generally considered of meteoric (1) origin, being allied with nickel and other metals. The immense quantity of iron imbedded in the coal formation is truly astonishing, and to account for its origin is a matter of no small difficulty. That the ironstone beds are deposits, is abundantly evident from the shells, fishes, and other remains found in them; but whence the matter came, no geologist yet, perhaps has been able to give a satisfactory explanation. It may have been ejected from the central parts of the earth by the means of chalybeate springs, or it may have resulted from the decomposition of vegetable matter as bog iron is supposed to have done. The hæmatitic iron ores occur in veins, penetrating other rocks: many of these appear to be inexhaustible. In the Missouri in North America, there is a mass of iron ore 300 feet in height, and several miles in length—in the Scottish coal formation, we have enumerated from 70 to 80 ironstone strata of different kinds and quality. Ironstone when roasted is attracted by the magnet, and may thus be distinguished from very fine grained basalt, and other rocks which resemble it.

*Zinc* does not occur native. Blende or the sulphuret of zinc, is the most common of its ores; it occurs most frequently in veins containing sulphurets of iron, lead, and copper. The metal itself is of a bluish white colour, with a fine granular (2) structure; mixed with copper it forms brass. The carbonate of zinc is called calamine.

*Tin* is a well known metal of a white brilliant colour. Its principal ore is the native oxide; the metal is obtained by heating the ore to redness with charcoal. This metal has been known since the earliest historical ages; it was in common use in the time of Moses, and was procured from Britain by the Phœnicians. The total value of tin ores sold in Britain in 1837, was £363,322 16*s*. 4*d*. The bronze of the ancients consisted of 88 or 90 parts of tin, with 10 or 12 of copper. Bell-metal consists generally of one-fifth of tin, and four-fifths of copper. The gongs of the Chinese are formed of four-fifths of copper, and one-fifth of tin. Tin occurs in rocks of granite, gneiss, in veins or fissures called lodes, and also in horizontal beds called floors.

*Cadmium* is a metal of a bluish white colour, it is less ductile or malleable than any of the metals which possess these properties, it has been found chiefly in certain ores of zinc in Germany and Derbyshire. The only real ore of cadmium, exists in the new mineral greenochite which is a sulphuret of cadmium. It is of a brilliant orange colour, and occurs in small crystals in the trap rocks of Renfrewshire, with prechnite and other minerals peculiar to that district. It affords a fine yellow pigment (3), but occurs in too small quantities to be useful.

*Antimony*. This metal has very much the appearance of zinc. The most abundant of its ores is the sulphuret, it combines so rapidly with chlorine that if it be poured upon it in a state of fine powder, into a glass jar filled with that gas, it produces a shower of fire. Combined with tin, it forms a kind of pewter; and with lead and copper, type-metal. Native antimony occurs in metallic veins in primitive rocks in Sweden and in the monntains of Hanover, Dauphiny, Hungary, Brazil and Mexico.

*Copper* has been known from the earliest times of which we have any record: it is found in the primitive and secondary rocks, often native, but chiefly as the sulphuret of copper, known by the name of copper pyrites. Copper has not been found combined with carbon, but it eombines with phosphorus: many of the copper ores are extremely beautiful. Copper is found in Europe, in France, Germany, Sweden, Norway; in Great Britain, particularly in Cornwall; Ireland, and Spain; and in many places in Asia, Africa and America. In Brazil a mass was once discovered, weighing 2666 pounds.

*Molybdenum* is of a whitish yellow colour externally, but the fracture (4) is of a whitish grey: it is obtained from the mineral molybdena, but is of no practical use.

*Uranium* is of a greyish colour; it gives a deep orange to the enamel of porcelain: it is not much used, from the great difficulty of obtaining it. It is found in Saxony and Cornwall.

*Tellurium* is found combined with ores of gold, in the gold mines of Transylvania. It is of a bluish white colour like tin. It is not used in any form.

*Chromium*. The protoxide (5) of chrome has been found native in France in the form of a green incrustation. It is the colouring matter of the emerald. Chromic acid gives the red tint to the ruby. Chromate of iron is found in small crystalline grains, and also massive. It is of a black colour with a slight metallic lustre. It is used in the manufacture of chromate of potash; and promises to be useful in the arts, as a source of some fine pigments. Chromate of lead is found only in Siberia. It is a very rare mineral; it occurs in crystals of a fine orange-red colour.

*Cerium*. The properties of this metal are but little known, and is obtained from the minerals cerite and allanite. It is described as a hard white brittle metal.

*Nickel* is found native combined with arsenic, and with arsenic acid. It is a hard white metal, malleable and ductile, and when pure may be rendered magnetic like iron. It occurs with iron in meteoric stones of which a notice will be given hereafter.

*Vanadium*. Its properties are yet unknown.

*Cobalt* is of a grey colour with a shade of red with scarcely any lustre. The fine blue mineral zaffre is an impure oxide of this metal. The principal use of cobalt is to give glass and porcelain a beautiful blue colour. Some of the varieties are crystallized: the finest specimens come from Saxony. The ores are compounds of the metal with iron, nickel, arsenic and sulphur.

*Lead*. This metal is too well known to need description. The lead ores are very numerous; but the most important is the sulphuret of lead, commonly called galena. Lead is found combined with the carbonic, sulphuric, arsenic, molybdic and chromic acids, and with oxygen and chlorine. Galena occurs in primitive as well as in secondary rocks in this country: the richest ores occur in greywacke slate and in mountain limestone.* Lead is found in this country principally in Derbyshire and Lancashire, and at Leadhills in Lanarkshire. It abounds in many places on the continent.

*Tungstenum* is a greyish hard metal, with a specific gravity of 17·4. It has been obtained native only in the form of grains of excessive hardness. It exists in the mineral tungsten in the proportion of 77·75 per cent. This mineral occurs in Cornwall, Sweden, and Bohemia.

*Mercury*. This metal is of the colour of burnished silver. It fuses at a temperature of 71° below the freezing point of water; consequently, under common circumstances, it is always found fluid. Native mercury occurs in small globules disseminated (6) in other metals; but it is from the sulphuret of mercury from which the metal is principally obtained. Sulphuret of mercury occurs in beds, or large irregular masses, and sometimes in veins. The mines which furnish this mineral are not common. Spain, Germany, and Peru, contain the most important. In Spain the mines are in clay slate and in shale. They are most unwholesome; and state criminals are sent hither to eke out a miserable existence: they soon lose their teeth, and are subject to paralysis, convulsions, and premature old age. Even the vapours are so obnoxious as to prevent the rearing of cattle and the growth of fruit or grain in the vicinity. Its various uses as an amalgam, (7) medicine, and for thermometrical and barometrical purposes, are well known.

*Columbium*. This metal is procured from the mineral tantalite. Berzelius, the only person who has obtained it in the metallic state, describes it as of the colour of iron, very hard, brittle, and burning at a red heat into a white oxide. It was originally discovered in America by Hatchett, and hence its name Columbium (8).

*Bismuth* is a metal of a cream or whitish red colour. It occurs in veins in primitive rocks, as gneiss, granite, and mica slate, in Saxony, Sweden, Bohemia, France, and Cornwall. One part of bismuth, with five of lead, form the soft solder used by pewterers; it is also used in the manufaeture of printers' types. Bismuth unites with most metals, rendering them generally remarkably fusible: hence its use as a solder. It is with a compound of two parts of bismuth, one of lead, one of tin, and four of mercury, the whole being fusible at a lower temperature than that of boiling water, that glass globes are silvered on the inside. A piece of this compound being placed within the globe, the latter is plunged into water; the metallic compound readily

* The other ores are found generally in the older rocks, but not in trap or in serpentine; in porphyry, in syenite, and in the lowest sandstones; also, occasionally, in coal strata.

melts, and the globe being turned round, the fluid metal is spread over the internal surface.

*Silver.* The ores of silver occur in metallic veins in primary rocks. Lead, and many other ores, contain silver. It is found in several places of Europe, yet the principal supply has always been from the mines of Mexico and Peru. The mines of Potosi are so rich in this mineral as to have paid £234,700,000 of duty. Native silver has the general character of the pure metal. It occurs in masses, in strings, ramified, in cubes, and in eight-sided crystals. It is seldom pure in the native state.

*Gold* occurs in nature in the metallic state, alloyed with a little silver or copper. In this state it is called native gold. It occurs in masses, in cubes, ramose (9), and in eight-sided crystals. Gold is found in veins, in primitive rocks, and in the alluvial (10) sands of rivers.

*Platinum* is the most infusible of all metals, and is of a white colour like silver, but not so bright. It was first found in Choco and Santa Fe, in South America; but has been since discovered in the Brazils, Spain, and in the Ural Mountains in Siberia. In the ore of platinum, the four new metals, iridium, palladium, osmium, and rhodium, have been detected.

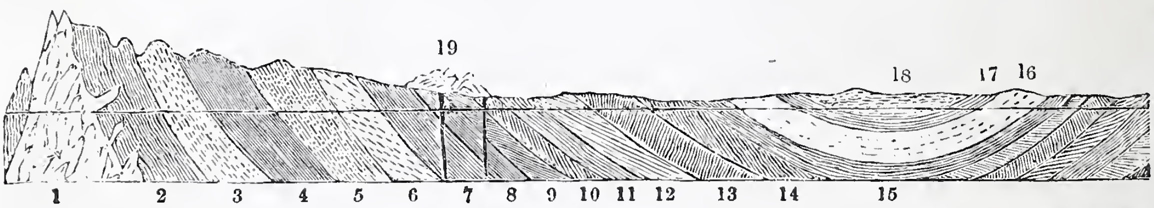
*Palladium* forms a hard durable alloy with gold, which has been used in the construction of mathematical instruments; and rhodium has been applied in making the points of metallic pens; iridium and osmium have not been applied to any useful purpose.

We have thus given a brief view of the elementary substances which enter into the composition of minerals, and other substances on the surface of the globe; from which it will readily appear, that a very few compose by far the greater proportion, and that these are the oxides, silica, alumina, lime, magnesia, and iron. More than nineteen-twentieths of the crust of the earth are composed of these ingredients.

The following tabular view and section will assist the student in understanding the position of the various rocks already alluded to, or which we shall have again occasion to mention.

(1) *Meteoric*, applied to those bodies which occasionally fall from the atmosphere in a red hot state. (2) Consisting of grains. (3) *Paint.* (4) That part of a mineral or metal exposed when broken. (5) *Protoxide*, containing the least quantity of oxygen. (6) *Disseminated*, distributed irregularly. (7) *Amalgam*, an article used in the process of assaying metals. (8) *Columbium*, from *Columbus*, the discoverer of America. (9) *Branched.* (10) *Alluvial*, matter deposited by rivers on the regular rocks.

SECTION OF THE CRUST OF THE EARTH.




1. Granite. 2. Gneiss. 3. Mica. 4. Clay slate. 5. Silurian rocks. 6. Old red sandstone. 7. Mountain limestone. 8. Lower coal formation. 9. Upper coal formation. 10. Lias. 11. Lower oolite. 12. Middle oolite. 13. Upper oolite. 14. Wealden. 15. Green sand. 16. Chalk. 17. Tertiary strata. 18. Recent formations. 19. Trap.

## BIOGRAPHY.

### JAMES FERGUSON.

[The following account of this miracle of self-instruction was drawn up by himself a few years before his death, and is one of the most interesting specimens of autobiography in the language.]

"I was born in the year 1710, a few miles from Keith, a little village in Banffshire, in the north of Scotland; and can with pleasure say, that my parents, though poor, were religious and honest; lived in good repute with all who knew them; and died with good characters.

"As my father had nothing to support a large family but his daily labour, and the profits arising from a few acres of land which he rented, it was not to be expected that he could bestow much on the education of his children: yet they were not neglected; for, in his leisure hours, he taught them to read and write. And it was while he was teaching my elder brother to read the Scottish catechism that I acquired my reading. Ashamed to ask my father to instruct me, I used, when he and my brother were abroad, to take the catechism, and study the lesson which he had been teaching my brother; and when any difficulty occurred. I went to a neighbouring old woman, who gave me such help as enabled me to read tolerably well before my father had thought of teaching me.

"Some time after, he was agreeably surprised to find me reading by myself: he thereupon gave me further instruction, and also taught me to write; which, with about three months I afterwards had at the grammar-school at Keith, was all the education I ever received.

"My taste for mechanics arose from an odd accident.—When about seven or eight years of age, a part of the roof of the house being decayed, my father, desirous of mending it, applied a prop and lever to an upright spar to raise it to its former situation; and, to my great astonishment, I saw him, without considering the reason, lift up the ponderous roof as if it had been a small weight. I attributed this at first to a degree of strength that excited my terror as well as wonder: but thinking further of the matter, I recollected, that he had applied his strength to that end of the lever which was furthest from the prop; and finding, on inquiry, that this was the means whereby this seeming wonder was effected, I began making levers (which I then called bars); and by applying weights to them different ways, I found the power gained by my bar was just in proportion to the lengths of the different parts of the bar on either side of the prop. I then thought it was a great pity, that, by means of this bar, a weight could be raised but a very little way. On this I soon imagined, that, by pulling round a wheel, the weight might be raised to any height, by tying a rope to the weight, and winding the rope round the axle of the wheel; and that the power gained must be just as great as the wheel was broader than the axle was thick; and found it to be exactly so, by hanging one weight to a rope put round the wheel, and another to the rope that coiled round the axle. So that, in these two machines, it appeared very plain, that their advantage was as great as the space gone through by the working power exceeded the space gone through by the weight. And this property I also thought must take place in a wedge for cleaving wood; but then I happened not to think of the screw. By means of a turning lathe which my father had, and sometimes used, and a little knife, I was enabled to make wheels and other things necessary for my purpose.

"I then wrote a short account of these machines, and sketched out figures of them with a pen, imagining it to be the first treatise of the kind that ever was written: but found my mistake, when I afterwards showed it to a gentleman, who told me that these things were known long before, and showed me a printed book in which they were treated of: and I was much pleased when I found, that my account (so far as I had carried it) agreed with the principles of mechanics in the book he showed me. And from that time my mind preserved a constant tendency to improve in that science.

"But as my father could not afford to maintain me while I was in pursuit only of these matters, and I was rather too young and weak for hard labour, he put me out to a neighbour to keep sheep, which I continued to do for some years; and in that time

I began to study the stars in the night. In the daytime I amused myself by making models of mills, spinning wheels, and such other things as I happened to see.

"I then went to serve a considerable farmer in the neighbourhood, whose name was James Glashan. I found him very kind and indulgent: but he soon observed, that in the evenings, when my work was over, I went into a field with a blanket about me, lay down on my back, and stretched a thread with small beads upon it, at arms-length, between my eye and the stars, sliding the beads upon it till they hid such and such stars from my eye, in order to take their apparent distances from one another; and then, laying the thread down on a paper, I marked the stars thereon by the beads, according to their respective positions, having a candle by me. My master at first laughed at me, but when I explained my meaning to him, he encouraged me to go on; and that I might make fair copies in the daytime of what I had done in the night, he often worked for me himself. —I shall always have a respect for the memory of that man.

"One day he happened to send me with a message to the Rev. Mr John Gilchrist, minister at Keith, to whom I had been known from my childhood. I carried my star-papers to show them to him, and found him looking over a large parcel of maps, which I surveyed with great pleasure, as they were the first I had ever seen. He then told me, that the earth is round like a ball, and explained the map of it to me. I requested him to lend me that map, to take a copy of it in the evenings. He cheerfully consented to this, giving me at the same time a pair of compasses, a ruler, pens, ink, and paper; and dismissed me with an injunction not to neglect my master's business by copying the map, which I might keep as long as I pleased.

"For this pleasant employment, my master gave me more time than I could reasonably expect; and often took the thrashing-flail out of my hands, and worked himself, while I sat by him in the barn, busy with my compasses, ruler, and pen.

"When I had finished the copy, I asked leave to carry home the map; he told me I was at liberty to do so, and might stay two hours to converse with the minister. In my way thither, I happened to pass by the school at which I had been before, and saw a genteel-looking man, whose name I afterwards learnt was Cantley, painting a sundial on the wall. I stopt a while to observe him, and the schoolmaster came out, and asked me what parcel it was that I had under my arm. I showed him the map, and the copy I had made of it, wherewith he appeared to be very well pleased; and asked me whether I should not like to learn of Mr Cantley to make sundials? Mr Cantley looked at the copy of the map, and commended it much; telling the schoolmaster, Mr John Skinner, that it was a pity I did not meet with notice and encouragement. I had a good deal of conversation with him, and found him to be quite affable and communicative; which made me think I should be extremely happy if I could be further acquainted with him.

"I then proceeded with the map to the minister, and showed him the copy of it. While we were conversing together, a neighbouring gentleman, Thomas Grant, Esq. of Achoynaney, happened to come in, and the minister immediately introduced me to him, showing him what I had done. He expressed great satisfaction, asked me some questions about the construction of maps, and told me, that if I would go and live at his house, he would order his butler, Alexander Cantley, to give me a great deal of instruction. Finding that this Cantley was the man whom I had seen painting the sundial, and of whom I had already conceived a very high opinion, I told squire Grant, that I should rejoice to be at his house as soon as the time was expired for which I was engaged with my present master. He very politely offered to put one in my place, but this I declined.

"When the term of my servitude was out, I left my good master, and went to the gentleman's house, where I quickly found myself with a most humane good family. Mr Cantley the butler soon became my friend, and continued so till his death. He was the most extraordinary man that I ever was acquainted with, or perhaps ever shall see; for he was a complete master of arithmetic, a good mathematician, a master of music on every known instrument except the harp, understood Latin, French, and Greek, let blood extremely well, and could even prescribe as a physician upon any urgent occasion. He was what is generally called self-taught; but I think he might with much greater propriety have been termed, God Almighty's scholar.

"He immediately began to teach me decimal arithmetic, and algebra; for I had already learned vulgar arithmetic, in my leisure hours from books. He then proceeded to teach me the elements of geometry; but, to my inexpressible grief, just as I was beginning that branch of science, he left Mr Grant, and went to the late earl of Fife's, at several miles distance. The good family I was then with could not prevail with me to stay after he was gone; so I left them, and went to my father's.

"He had made me a present of Gordon's Geographical Grammar, which, at that time, was to me a great treasure. There is no figure of a globe in it, although it contains a tolerable description of the globes, and their use. From this description I made a globe in three weeks at my father's, having turned the ball thereof out of a piece of wood; which ball I covered with paper, and delineated a map of the world upon it, made the meridian ring and horizon of wood, covered them with paper, and graduated them; and was happy to find, that by my globe, which was the first I ever saw, I could solve the problems.

"But this was not likely to afford me bread; and I could not think of staying with my father, who, I knew full well, could not maintain me in that way, as it could be of no service to him; and he had, without my assistance, hands sufficient for all his work.

"I then went to a miller, thinking it would be a very easy business to attend the mill, and that I should have a great deal of leisure time to study decimal arithmetic and geometry. But my master, being too fond of tippling at an alehouse, left the whole care of the mill to me, and almost starved me for want of victuals; so that I was glad when I could have a little oatmeal mixed with cold water to eat. I was engaged for a year in that man's service; at the end of which I left him, and returned in a very weak state to my father's.

"Soon after I had recovered my former strength, a neighbouring farmer, who practised as a physician in that part of the country, came to my father's, wanting to have me as a labouring servant. My father advised me to go to Dr Young, telling me that the doctor would instruct me in that part of his business. This he promised to do, which was a temptation to me. But instead of performing his promise, he kept me constantly at very hard labour, and never once showed me one of his books. All his servants complained that he was the hardest master they had ever lived with; and it was my misfortune to be engaged with him for half-a-year. But at the end of three months I was so much overwrought, that I was almost disabled, which obliged me to leave him; and he was so unjust as to give me nothing at all for the time I had been with him, because I did not complete my half-year's service; though he knew that I was not able, and had seen me working for the last fortnight as much as possible with one hand and arm, when I could not lift the other from my side. And what I thought was particularly hard, he never once tried to give me the least relief, farther than once bleeding me, which rather did me hurt than good, as I was very weak, and much emaciated. I then went to my father's, where I was confined for two months on account of my hurt, and despaired of ever recovering the use of my left arm. And during all that time the doctor never once came to see me, although the distance was not quite two miles. But my friend Mr Cantley, hearing of my misfortune at twelve miles' distance, sent me proper medicines and applications, by means of which I recovered the use of my arm; but found myself too weak to think of going into service again, and had entirely lost my appetite, so that I could take nothing but a draught of milk once a-day, for many weeks.

"In order to amuse myself in this low state, I made a wooden clock, the frame of which was also of wood; and it kept time pretty well. The bell on which the hammer struck the hours was the neck of a broken bottle. Having then no idea how any timekeeper could go but by a weight and a line, I wondered how a watch could go in all positions, and was sorry that I had never thought of asking Mr Cantley, who could very easily have informed me. But happening one day to see a gentleman ride by my father's house, which was close by a public road, I asked him what o'clock it then was: he looked at his watch, and told me. As he did that with so much good nature, I begged of him to show me the inside of his watch; and though he was an entire stranger, he immediately opened the watch, and put it into my hands. I saw the spring-box with part of the chain round it, and asked him what it was that made the box turn round; he told me that it was turned round by a steel spring within it. Hav-

ing then never seen any other spring than that of my father's gun-lock, I asked how a spring within a box could turn the box so often round as to wind all the chain upon it. He answered that the spring was long and thin, that one end of it was fastened to the axis of the box, and the other end to the inside of the box, that the axis was fixed, and the box was loose upon it. I told him I did not yet thoroughly understand the matter:—'Well, my lad,' says he, 'take a long thin piece of whalebone, hold one end of it fast between your finger and thumb, and wind it round your finger, it will then endeavour to unwind itself; and if you fix the other end of it to the inside of a small hoop, and leave it to itself, it will turn the hoop round and round, and wind up a thread tied to the outside of the hoop.'—I thanked the gentleman, and told him that I understood the thing very well. I then tried to make a watch with wooden wheels, and made the spring of whalebone; but found that I could not make the watch go when the balance was put on, because the teeth of the wheels were rather too weak to bear the force of a spring sufficient to move the balance; although the wheels would run fast enough when the balance was taken off. I enclosed the whole in a wooden case very little bigger than a breakfast tea-cup; but a clumsy neighbour one day looking at my watch, happened to let it fall, and turning hastily about to pick it up, set his foot upon it, and crushed it all to pieces; which so provoked my father, that he was almost ready to beat the man, and discouraged me so much that I never attempted to make such another machine again, especially as I was thoroughly convinced I could never make one that would be of any real use.

"As soon as I was able to go abroad, I carried my globe, clock, and copies of some other maps besides that of the world, to the late Sir James Dunbar of Durn, about seven miles from where my father lived, as I had heard that Sir James was a very good-natured, friendly, inquisitive gentleman. He received me in a very kind manner, was pleased with what I showed him, and desired I would clean his clocks. This, for the first time, I attempted; and then began to pick up some money in that way about the country, making Sir James's house my home at his desire.

"Two large globular stones stood on the top of his gate; on one of them I painted with oil colours a map of the terrestrial globe, and on the other a map of the celestial, from a planisphere of the stars which I copied on paper from a celestial globe belonging to a neighbouring gentleman. The poles of the painted globes stood toward the poles of the heavens; on each the twenty-four hours were placed around the equinoctial, so as to show the time of the day when the sun shone out, by the boundary where the half of the globe at any time enlightened by the sun, was parted from the other half in the shade; the enlightened parts of the terrestrial globe answering to the like enlightened parts of the earth at all times. So that whenever the sun shone on the globe one might see to what places the sun was then rising, to what places it was setting, and all the places where it was then day or night, throughout the earth.

"During the time I was at Sir James's hospitable house, his sister, the honourable lady Dipple came there on a visit, and Sir James introduced me to her. She asked me whether I could draw patterns for needlework on aprons and gowns. On showing me some, I undertook the work, and drew several for her; some of which were copied from her patterns, and the rest I did according to my own fancy. On this, I was sent for by other ladies in the country, and began to think myself growing very rich by the money I got for such drawings, out of which I had the pleasure of occasionally supplying the wants of my poor father.

"Yet all this while I could not leave off stargazing in the nights, and taking the places of the planets among the stars by my above-mentioned thread. By this, I could observe how the planets changed their places among the stars, and delineated their paths on the celestial map, which I had copied from the above-mentioned celestial globe.

"By observing what constellations the ecliptic passed through in that map, and comparing these with the starry heaven, I was so impressed as sometimes to imagine that I saw the ecliptic in the heaven, among the stars like a broad circular road for the sun's apparent course; and fancied the paths of the planets to resemble the narrow ruts made by cart-wheels, sometimes on one side of a plain road, and sometimes on the other, crossing the road at small angles, but never going far from either side of it.

"Sir James's house was full of pictures and prints, several of which I copied with pen and ink; this made him think I might become a painter.

"Lady Dipple had been but a few weeks there when William Baird, Esq. of Auchmedden came on a visit; he was the husband of one of that lady's daughters, and I found him to be very ingenious and communicative; he invited me to go to his house, and stay some time with him, telling me that I should have free access to his library, which was a very large one, and that he would furnish me with all sorts of implements for drawing. I went thither, and stayed about eight months; but was much disappointed in finding no books of astronomy in his library, except what was in the two volumes of Harris's Lexicon Technicum, although there were many books on geography and other sciences. Several of these indeed were in Latin, and more in French, which being languages that I did not understand, I had recourse to him for what I wanted to know of these subjects, which he cheerfully read to me; and it was as easy for him at sight to read English from a Greek, Latin, or French book, as from an English one. He furnished me with pencils and Indian ink, showing me how to draw with them; and although he had but an indifferent hand at that work, yet he was a very acute judge, and consequently a very fit person for showing me how to correct my own work. He was the first who ever sat to me for a picture; and I found it was much easier to draw from the life than from any picture whatever, as nature was more striking than any imitation of it.

"Lady Dipple came to his house in about half a year after I went thither; and as they thought I had a genius for painting, they consulted together about what might be the best way to put me forward. Mr Baird thought it would be no difficult matter to make a collection for me among the neighbouring gentlemen, to put me to a painter at Edinburgh; but he found, upon trial, that nothing worth the while could be done among them; and as to himself, he could not do much that way, because he had but a small estate, and a very numerous family.

"Lady Dipple then told me that she was to go to Edinburgh next spring, and that if I would go thither, she would give me a year's bed and board at her house, gratis; and make all the interest she could for me among her acquaintance there. I thankfully accepted of her kind offer; and instead of giving me one year, she gave me two. I carried with me a letter of recommendation from the lord Pitsligo, a near neighbour of squire Baird's, to Mr John Alexander, a painter in Edinburgh, who allowed me to pass an hour every day at his house, for a month, to copy from his drawings; and said he would teach me to paint in oil-colours if I would serve him seven years, and my friends would maintain me all that time; but this was too much for me to desire them to do, nor did I choose to serve so long. I was then recommended to other painters, but they would do nothing without money; so I was quite at a loss what to do.

"In a few days after this, I received a letter of recommendation from my good friend squire Baird, to the Rev. Dr Robert Keith at Edinburgh, to whom I gave an account of my bad success among the painters there. He told me, that if I would copy from nature, I might do without their assistance, as all the rules for drawing signified but very little when one came to draw from the life; and by what he had seen of my drawings brought from the north, he judged I might succeed very well in drawing pictures from the life, in Indian ink, on vellum. He then sat to me for his own picture, and sent me with it, and a letter of recommendation, to the right honourable the lady Jane Douglas, who lived with her mother, the marchioness of Douglas, at Merchiston-house, near Edinburgh. Both the marchioness and lady Jane behaved to me in the most friendly manner, on Dr Keith's account, and sat for their pictures, telling me at the same time, that I was in the very room in which lord Napier invented and computed the logarithms; and that if I thought it would inspire me, I should always have the same room whenever I came to Merchiston. I stayed there several days, and drew several pictures of lady Jane, of whom it was hard to say, whether the greatness of her beauty, or the goodness of her temper and disposition, was the most predominant. She sent these pictures to ladies of her acquaintance, in order to recommend me to them; by which means I soon had as much business as I could possibly manage, so as not only to put a good deal of money in my own pocket, but also to spare what was sufficient to help to supply my father and mother in their old age. Thus a business was pro-

videntially put into my hands, which I followed for six-and-twenty years.

"Lady Dipple, being a woman of the strictest piety, kept a watchful eye over me at first, and made me give her an exact account at night of what families I had been in throughout the day, and of the money I had received. She took the money each night, desiring I would keep an account of what I had put into her hands; telling me, that I should duly have out of it what I wanted for clothes, and to send to my father. But in less than half-a-year, she told me that she would thenceforth trust me with being my own banker; for she had made a good deal of private inquiry how I had behaved when I was out of her sight through the day, and was satisfied with my conduct.

"During my two years' stay at Edinburgh, I somehow took a violent inclination to study anatomy, surgery, and physic, all from reading of books, and conversing with gentlemen on these subjects, which for that time put all thoughts of astronomy out of my mind; and I had no inclination to become acquainted with any one there who taught either mathematics or astronomy, for nothing would serve me but to be a doctor.

"At the end of the second year I left Edinburgh, and went to see my father, thinking myself tolerably well qualified to be a physician in that part of the country, and I carried a good deal of medicines, plasters, &c., thither; but to my mortification I soon found that all my medical theories and study were of little use in practice. And then, finding that very few paid me for the medicines they had, and that I was far from being so successful as I could wish, I quite left off that business, and began to think of taking to the more sure one of drawing pictures again. For this purpose I went to Inverness, where I had eight months' business.

"When I was there, I began to think of astronomy again, and was heartily sorry for having quite neglected it at Edinburgh, where I might have improved my knowledge by conversing with those who were able to assist me. I began to compare the ecliptic with its twelve signs, through which the sun goes in twelve months, to the circle of twelve hours on the dial-plate of a watch, the hour-hand to the sun, and the minute hand to the moon, moving in the ecliptic, the one always overtaking the other at a place forwarder than it did at their last conjunction before. On this, I contrived and finished a scheme on paper, for showing the motions and places of the sun and moon in the ecliptic on each day of the year, perpetually; and consequently, the days of all the new and full moons.

"To this I wanted to add a method for showing the eclipses of the sun and moon; of which I knew the cause long before, by having observed that the moon was for one half of her period on the north side of the ecliptic, and for the other half on the south. But not having observed her course long enough among the stars by my above mentioned thread, so as to delineate her path on my celestial map, in order to find the two opposite points of the ecliptic in which her orbit crosses it, I was altogether at a loss how and where in the ecliptic, in my scheme, to place those intersecting points: this was in the year 1739.

"At last, I recollected that when I was with squire Grant of Auchoynaney, in the year 1730, I had read, that on the 1st of January, 1690, the moon's ascending node was in the 10th minute of the first degree of Aries; and that her nodes moved backward through the whole ecliptic in 18 years and 224 days, which was at the rate of 3 minutes 11 seconds every 24 hours. But as I scarce knew in the year 1730 what the moon's nodes meant, I took no farther notice of it at that time.

"However, in the year 1739, I set to work at Inverness; and after a tedious calculation of the slow motion of the nodes from January 1690, to January 1740, it appeared to me, that (if I was sure I had remembered right,) the moon's ascending node must be in 23 degrees 25 minutes of Cancer at the beginning of the year 1740. And so I added the eclipse part to my scheme, and called it, the Astronomical Rotula.

"When I had finished it, I showed it to the Rev. Alexander Macbean, one of the ministers at Inverness; who told me he had a set of almanacs by him for several years past, and would examine it by the eclipses mentioned in them. We examined it together, and found that it agreed throughout with the days of all the new and full moons and eclipses mentioned in these almanacs; which made me think I had constructed it upon true astronomical principles. On this, Mr Macbean desired me to write to Mr Maclaurin, professor of mathematics at Edinburgh, and give him an account of the methods by which I had formed my plan, requesting him to correct it where it was wrong. He returned me a most polite and friendly answer, although I had never seen him during my stay at Edinburgh, and informed me, that I had only mistaken the radical mean place of the ascending node by a quarter of a degree; and that if I would send the drawing of my rotula to him, he would examine it, and endeavour to procure me a subscription to defray the charges of engraving it on copper-plates, if I chose to publish it. I then made a new and correct drawing of it, and sent it to him; who soon got me a very handsome subscription, by setting the example himself, and sending subscription papers to others.

"I then returned to Edinburgh, and had the rotula-plates engraved there by Mr Cooper.* It has gone through several impressions; and always sold very well till the year 1752, when the style was changed, which rendered it quite useless. Mr Maclaurin received me with the greatest civility when I first went to see him at Edinburgh. He then became an exceeding good friend to me, and continued so till his death.

"One day I requested him to show me his orrery, which he immediately did; I was greatly delighted with the motions of the earth and moon in it, and would gladly have seen the wheel-work, which was concealed in a brass box, and the box and planets above it were surrounded by an armillary sphere. But he told me, that he never had opened it; and I could easily perceive that it could not be opened but by the hand of some ingenious clock-maker, and not without a great deal of time and trouble.

"After a good deal of thinking and calculation, I found that I could contrive the wheel-work for turning the planets in such a machine, and giving them their progressive motions; but should be very well satisfied if I could make an orrery to show the motions of the earth and moon, and of the sun round its axis. I then employed a turner to make me a sufficient number of wheels and axles, according to patterns which I gave him in drawing; and after having cut the teeth in the wheels by a knife, and put the whole together, I found that it answered all my expectations. It showed the sun's motion round its axis, the diurnal and annual motions of the earth on its inclined axis, which kept its parallelism in its whole course round the sun; the motions and phases of the moon, with the retrograde motion of the nodes of her orbit; and consequently, all the variety of seasons, the different lengths of days and nights, the days of the new and full moons, and eclipses.

"When it was all completed except the box that covers the wheels, I showed it to Mr Maclaurin, who commended it in presence of a great many young gentlemen who attended his lectures. He desired me to read them a lecture on it, which I did without any hesitation, seeing I had no reason to be afraid of speaking before a great and good man who was my friend. Soon after that, I sent it as a present to the reverend and ingenious Mr Alexander Irvine, one of the ministers at Elgin, in Scotland.

"I then made a smaller and neater orrery, of which all the wheels were of ivory, and I cut the teeth in them with a file. This was done in the beginning of the year 1743; and in May, that year, I brought it with me to London, where it was soon after bought by Sir Dudley Rider. I have made six orreries since that time, and there are not any two of them in which the wheel-work is alike, for I could never bear to copy one thing of that kind from another, because I still saw there was great room for improvement.

"I had a letter of recommendation from Mr Baron Eldin at Edinburgh, to the right honourable Stephen Poyntz, Esq., at St James's, who had been preceptor to his royal highness the late Duke of Cumberland, and was well known to be possessed of all the good qualities that can adorn a human mind. To me, his goodness was really beyond my power of expression; and I had not been a month in London till he informed me, that he had written to an eminent professor of mathematics to take me into his house, and give me board and lodging, with all proper instructions to qualify me for teaching a mathematical school he (Mr Poyntz) had in view for me, and would get me settled in it. This I should have liked very well, especially as I began to be tired of drawing pictures; in which, I confess, I never strove to excel, because my mind was still pursuing things more agreeable. He soon after told me, he had just received an answer from the

* Cooper was master to the justly celebrated Mr. Robert Strange, who was at that time his apprentice.

mathematical master, desiring I might be sent immediately to him. On hearing this, I told Mr Poyntz that I did not know how to maintain my wife during the time I must be under the master's tuition. What, says he, are you a married man? I told him I had been so ever since May, in the year 1739. He said he was sorry for it; because it quite defeated his scheme, as the master of the school he had in view for me must be a bachelor.

"He then asked me what business I intended to follow? I answered, that I knew of none besides that of drawing pictures. On this he desired me to draw the pictures of his lady and children, that he might show them, in order to recommend me to others; and told me, that when I was out of business I should come to him, and he would find me as much as he could; and I soon found as much as I could execute, but he died in a few years after, to my inexpressible grief.

"Soon afterward, it appeared to me, that although the moon goes round the earth, and that the sun is far on the outside of the moon's orbit, yet the moon's motion must be in a line, that is, always concave towards the sun; and upon making a delineation, representing her absolute path in the heavens, I found it to be really so. I then made a simple machine for delineating both her path and the earth's on a long paper laid on the floor. I carried the machine and delineation to the late Martin Folkes, Esq., president of the Royal Society, on a Thursday afternoon. He expressed great satisfaction at seeing it, as it was a new discovery; and took me that evening with him to the Royal Society, where I showed the delineation, and the method of doing it.

"When the business of the society was over, one of the members desired me to dine with him next Saturday at Hackney, telling me that his name was Ellicott, and that he was a watchmaker.

"I accordingly went to Hackney, and was kindly received by Mr John Ellicott, who then showed me the very same kind of delineation, and part of the machine by which he had done it; telling me that he had thought of it twenty years before. I could easily see by the colour of the paper, and of the ink lines upon it, that it must have been done many years before I saw it. He then told me what was very certain, that he had neither stolen the thought from me, nor had I from him. And from that time till his death, Mr Ellicott was one of my best friends. The figure of this machine and delineation is in the 7th plate of my book of Astronomy.

"Soon after the style was changed, I had my rotula new engraved; but have neglected it too much, by not fitting it up and advertising it. After this, I drew out a scheme, and had it engraved, for showing all the problems of the rotula except the eclipses; and in place of that, it shows the times of rising and setting of the sun, moon, and stars; and the positions of the stars for any time of the night.

"In the year 1747, I published a dissertation on the phenomena of the harvest moon, with the description of a new orrery, in which there are only four wheels. But having never had grammatical education, nor time to study the rules of just composition, I acknowledge that I was afraid to put it to the press; and for the same cause I ought to have the same fears still. But having the pleasure to find that this my first work was not ill received, I was emboldened to go on, in publishing my Astronomy, Mechanical Lectures, Tables and Tracts relative to several arts and sciences, the Young Gentleman and Lady's Astronomy, and a small treatise on Electricity, and Select Mechanical Exercises.

"In the year 1748, I ventured to read lectures on the eclipse of the sun that fell on the 14th of July in that year. Afterwards I began to read astronomical lectures on an orrery which I made, and of which the figures of all the wheel-work are contained in the 6th and 7th plates of my Select Mechanical Exercises. I next began to make an apparatus for lectures on mechanics, and gradually increased the apparatus for other parts of experimental philosophy, buying from others what I could not make for myself, till I brought it to its present state. I then entirely left off drawing pictures, and employed myself in the much pleasanter business of reading lectures on mechanics, hydrostatics, hydraulics, pneumatics, electricity, and astronomy; in all which, my encouragement has been greater than I could have expected.

"The best machine I ever contrived is the eclipsareon, of which there is a figure in the 13th plate of my Astronomy. It shows the time, quantity, duration, and progress of solar eclipses, at all parts of the earth. My next best contrivance is the universal dialling cylinder, of which there is a figure in the 8th plate of the supplement to my Mechanical Lectures.

"It is now thirty years since I came to London, and during all that time I have met with the highest instances of friendship from all ranks of people, both in town and country, which I do here acknowledge with the utmost respect and gratitude; and particularly the goodness of our present gracious sovereign, who, out of his privy purse, allows me fifty pounds a-year, which is regularly paid without any deduction."

Here Ferguson's own narrative ends. Before his death he was admitted a member of the Royal Society without paying the initiatory or annual fees, an honour which had been conferred on the illustrious Newton, and the ingenious and self-taught mathematician, Thomas Simson of Woolwich; but generally reserved for distinguished foreigners. On many occasions he received marks of attention from George III., who attended some of the lectures of the ingenious astronomer, and often sent for him to converse upon scientific subjects. From an idea that he was extremely poor, Ferguson received many handsome presents; but to the astonishment of all who knew him, he left upwards of £6000 at his death, which happened on the 16th November, 1776, in the 66th year of his age.

"Ferguson," says Dr Hutton, "must be allowed to have been a very uncommon genius, especially in mechanical contrivances and inventions. * * * His general mathematical knowledge was little or nothing. Of algebra he understood little more than the notation; and he often told me that he could never demonstrate one proposition of Euclid's Elements, his constant method being to satisfy himself as to the truth of any problem with a measurement by scale and compasses." To this Sir David Brewster adds—"He possessed a clear judgment, and was capable of thinking and writing on philosophical subjects with great accuracy and precision. He had a peculiar talent for simplifying what was complex, for rendering intelligible what was abstract, and for bringing down to the lowest capacities what was naturally above them. His unwearied assiduity in the acquisition of knowledge may be inferred from the great variety of his publications; and when we reflect upon the very unfavourable circumstances in which he was educated, and the little assistance which he received from others, we cannot fail to wonder at the style in which all his works are composed. On some occasions, his style is uncommonly correct and animated. When admiring the displays of wisdom and beneficence in the economy of nature, he often rises into a species of eloquence, characterized by the most artless simplicity, and infinitely more affecting than the laboured and polished periods of the professed orator. In his manners he was affable and mild; in his dispositions communicative and benevolent. He was distinguished by none of those peculiarities of temper, and eccentricities of conduct, which we generally observe in literary men. If Mr Ferguson had any foibles, they 'leaned to virtue's side;' and even his wonderful simplicity of character, which, in a state of artificial manners, is too apt to be regarded as a failing, and exposed to ridicule and scorn, tended only to heighten the respect in which he was constantly held."

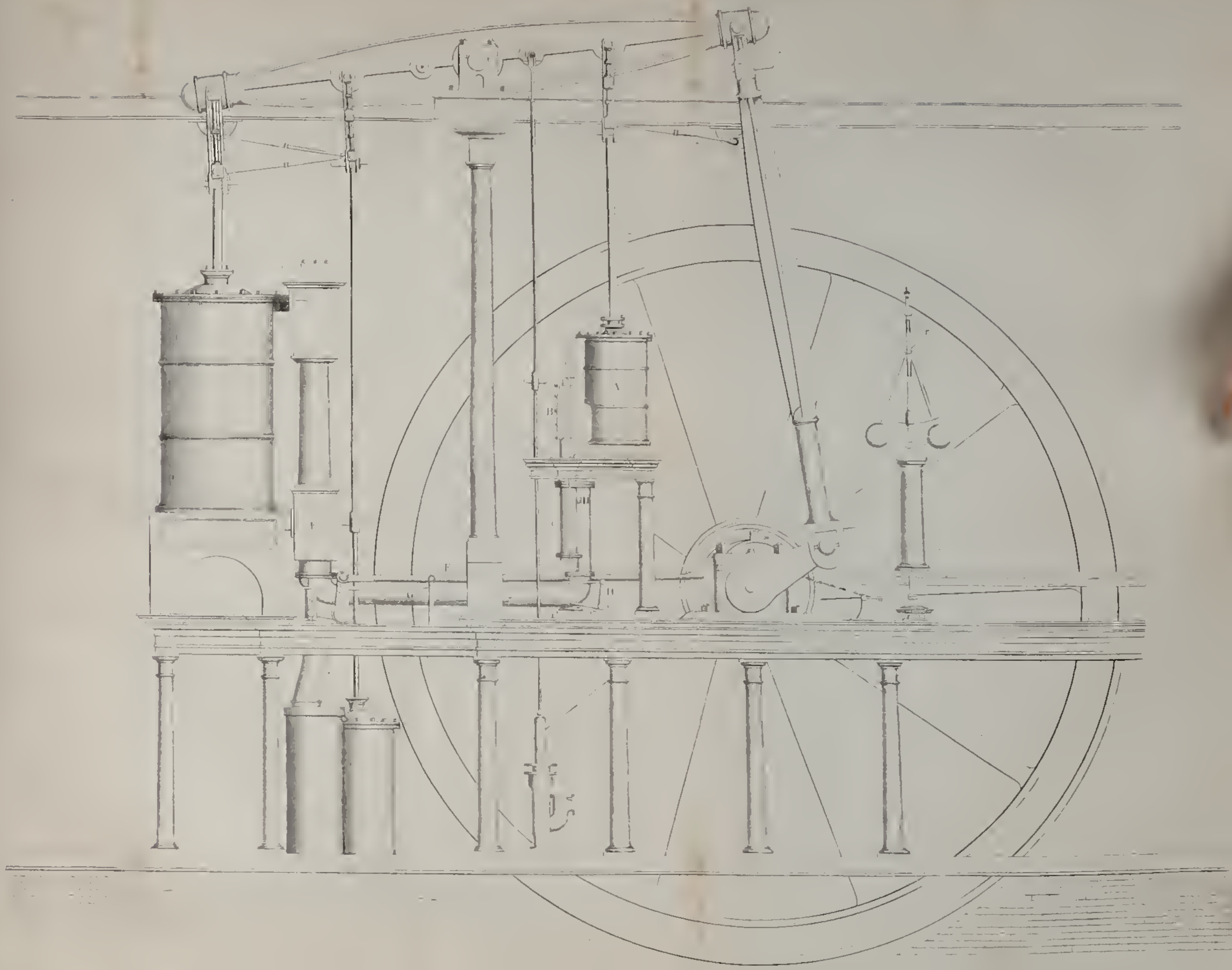
The astronomer is thus elegantly noticed by Capel Lloft, in his poem on the Universe:—

> "Nor shall thy guidance but conduct our feet,
> O honoured shepherd of our latest days!
> Thee, from the flocks, while thy untutored soul,
> Nature in childhood, traced the starry course,
> Astronomy, enamoured, gently led
> Through all the splendid labyrinths of heaven,
> And taught thee her stupendous laws; and clothed,
> In all the light of fair simplicity,
> Thy apt expression."

## M'NAUGHT'S DOUBLE CYLINDER STEAM-ENGINE.

It is a remarkable fact, and one which, even in the midst of our endless number of engineering improvements, powerfully exemplifies the proneness of the present generation of mankind to follow in the well-trodden footsteps of their fathers, regardless of the advantages which would undoubtedly arise from the striking out

Mc NAUGHT'S DOUBLE CYLINDER STEAM ENGINE.



a new route, that no one has hitherto "taken thought" to give to the world a cheap method of providing auxiliary power for machinery.

A manufacturer erects a mill, or an ironmaster a forge, and provides an engine suited for the then extent of his works. In a few years he probably wishes to conduct his operations on an increased scale, and cogitates upon the best mode of obtaining the requisite amount of driving power for the purpose. He finds, however, that this is a matter which involves a far greater series of inconveniencies than he had originally contemplated—of the different schemes for overcoming the difficulty, he vacillates between two, firstly, the substitution of a more powerful engine for his present over worked machine, and secondly, that long-cherished panacea for this evil, the application of a larger cylinder to his already well-strained engine framing. The former scheme is expensive, not only in first cost, but in the enormous loss of time incurred by the operation. The latter, although inexpensive in its application, eventually weighs pretty heavily in the balance of expenses for repairs.

We are indebted to Mr M'Naught for the introduction of a more feasible plan—where, by combining Woolf's principle with the common low pressure engine, he produces a comparatively inexpensive auxiliary power.

The illustration in our present number is an elevation of the condensing engine used for driving the cotton works of Messrs. Bartholomew & Co., at Barrowfield, having Mr. M'Naught's additional high pressure cylinder A applied to it.

The original power of this engine was 136 indicated horses, and the increase proposed to be made is 80 horses additional. The cylinder A is 30 inches diameter; its cubical contents, with regard to the low pressure cylinder, being as 4 to 1. It is supported upon the framing by means of four pillars, surmounted by an entablature, upon which the cylinder is bolted. The point of connection of the piston-rod, with the beam, is exactly midway between the working centre and the connecting-rod end, advantage being thus taken of the pump-rod and parallel motion eye, which is generally to be found in beam engines at this point.

The cylinder is fitted up with a common three-ported slide valve, as seen at B, the supply of high pressure steam to which, is conveyed by the pipe C, shown broken at its lower extremity. The steam, after acting upon the piston of this cylinder, passes along the pipe D to the nozzles E of the low pressure cylinder. Here it acts expansively in the ratio of 4 to 1,—the relative capacities of the two cylinders. The valve gearing, connected with both cylinders, is worked by one common eccentric rod F—the connection of the valve of the small cylinder, with the rocking shaft gearing of the larger one, being effected by means of the rod G, which works a second rocking shaft H, communicating with the side rods of the valve B. The throttle valve is placed in the high pressure steam-pipe at D, and is connected to the governor slide by a series of levers, &c. running beneath the floor line.

In the instance before us, the cold water pump is dispensed with, as the supply of condensing water flows direct from a reservoir; but, as is usually the case where this pump is necessary, it is easily worked from its originally intended position on the beam by an addition to the small cylinder piston-rod. Upon this rod is attached a cross-head, which carries at its extremities a pair of side-rods passing downwards outside the cylinder, beneath which they are again joined by a cross-tail. To the centre of this is attached the pump-rod passing direct to the pump, which is placed as usual beneath the floor of the engine-house.

This engine in its original state was worked by a set of four waggon boilers, 25 feet long, 6 ft. 6 in. wide, and 8 ft. 6 in. deep, without any internal flue, the steam pressure being $6\frac{1}{2}$ lbs. per square inch. These have been replaced by six high pressure boilers, each 25 feet long, and 4 feet 6 inches diameter, with hemispherical ends, without an internal flue.

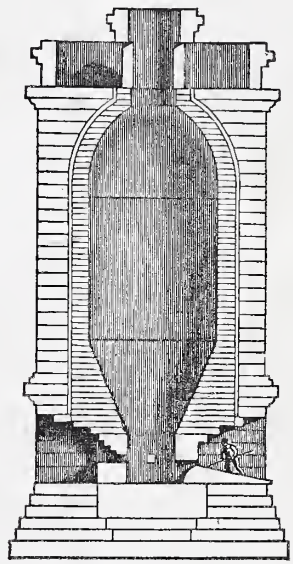
The steam pressure now used is about 30 lbs., but this is intended to be increased to 40 lbs. when the additional machinery is added, and the speed of the engine has been increased from $18\frac{1}{2}$ or 19 to 24 strokes per minute.

## THE PROPERTIES OF HOT AND COLD BLAST CAST-IRON.

The principal ore of iron smelted in Britain, is the clay iron stone of the coal measures. This is always a carbonate of iron (composed of oxide of iron and carbonic acid), but it is never absolutely pure, and it varies in this respect considerably even in specimens from the same bed. The mean richness of the ore in the principal fields may be taken at about 33 per cent. of metal; but the rich Welch ore sometimes contains as much as 89 per cent. of carbonate, or 42 of metal; and the richer beds of Dudley and of Lanarkshire yield as much as 85 per cent. of carbonate or 40 of metal. The extraneous matters with which the carbonate is usually associated are, lime, magnesia, silica and alumina, with commonly a little manganese. These matters are exceedingly variable in quantity. Sometimes the silica and alumina together constitute 45 per cent. of the ore; at other times they are entirely wanting; and the lime and magnesia are equally inconstant.

The presence of these foreign matters in the ore from which our cast-iron is obtained, explains why that substance has always associated with it some impurity or other. The method by which the ore is smelted will render this obvious.

The ore, before it is put into the furnace, is broken into moderately sized pieces and roasted; that is, baked by a method very similar to the burning of bricks in clumps. This process drives off the carbonic acid from the carbonate of iron, and reduces the weight of the ore from 25 to 30 per cent. It is now ready to be placed in the smelting furnace, which is a hollow brick building in the form of a tower, from 40 to 50 feet high. The figure exhibits in section an approved furnace of the sort.



[The above figure shows a vertical section of the furnace at right angles to two of the tuyère holes, and in the plane of the third tuyère and the tymp-hole at which the metal is run off.]

The roasted ore is mixed in the furnace with limestone (any carbonate of lime), and with coke, if the cold blast is to be employed in the smelting process; or simply with common coal, if the hot blast is to be employed. The use of the limestone is to act as a flux upon the earths in connexion with the ore, upon the well-known principle that it melts with the clay into a liquid glass when sufficiently heated; and by doing so in the operation of smelting, it removes the argillaceous matter from the ore, and

allows the oxide of iron to come into contact with the ignited coals which reduce it to the metallic state by withdrawing its oxygen. The fire is urged to intensity during the operation by forcing into it a current of air either at the ordinary temperature or heated up by appropriate apparatus to about 612°: it thus constitutes according to the temperature at which it is employed, the *cold* or the *hot blast.* The vitrified materials rise and float upon the surface of the melted mass, and are termed *scoria* or *slag ;* and the melted metal is run off at an opening at the bottom of the furnace and is conveyed into sand-moulds laid upon the ground, or simply into furrows made in sand. The large mass which sets in the main furrow is called by the workmen a *sow*, and the lesser ones are *pigs*, and hence this sort of iron is generally known by the name of *pig* or *crude* iron.

It was, till lately, the general opinion that the difference between cast iron and malleable iron consisted solely in the presence of carbon, (charcoal) in the former ; or, in other words, that cast iron was simply what chemists call a carburet of iron, and that its different degrees of hardness depended entirely on the difference in the degrees of its carbonization. Thus the iron known to founders as No. 1, and which is the softest under the file and chisel, and possesses but a moderate tenacity, was considered to possess an excess of carbon. By re-melting this, it passes into No. 2, which is lighter in the shade than No. 1, is more tenacious, is easily turned and polished, and makes the finest castings ; this modification of quality was attributed solely to the loss of carbon in the process of re-melting. Again, by repeated melting, No. 2 passes into No. 3, called white cast iron. This is possessed of less fluidity, is hard and brittle, and makes very rough castings ; properties attributed to the yet less admixture of carbon.

There is no doubt that the opinion concerning the degrees of carbonization, and the results attributed to that cause, are in the main correct ; but there are other ingredients which enter into the composition of cast iron, and seem to modify its qualities almost as much as the varying admixture of carbon itself. Thus, Dr Thomson has shown that manganese, silicon, and aluminum (the bases of silica and alumina), are united with carbon in the composition of all cast iron ; and that sulphur, calcium, and magnesium, (the bases of lime and magnesia), are sometimes present ; and I may add, that arsenic, copper, sulphur, and several other impurities are not often entirely absent. These all affect the quality of the iron in proportion to their quantities, which are variable, and particularly so according as the iron is manufactured by the cold or hot blast. Overlooking the inconstant matters, sulphur, calcium, magnesium, &c., the constant constitution of cold blast cast iron is stated by Dr. Thomson as follows :—

| | | | |
|---|---|---|---|
| Iron, | 77· | = | 22 atoms. |
| Manganese, | 1·75 | = | $\frac{1}{2}$ atom. |
| Carbon, | 3·27 | = | 4·36 atoms. |
| Silicon, | 1· | = | 1 atom. |
| Aluminum, | 1·4 | = | $1\frac{1}{8}$ atom. |

and uniting the iron and manganese, and considering them as acting the part of bases, to which the carbon, silicon, and aluminum unite in definite proportions, we have $22\frac{1}{2}$ atoms iron and manganese, $6\frac{1}{2}$ atoms carbon, silicon, and aluminum ; or what is the same, $3\frac{1}{2}$ atoms iron and manganese, and 1 atom carbon, silicon and aluminum. But the proportions of these three constituents are so very nearly 4 atoms of carbon, 1 atom of silicon, and 1 atom of aluminum, that we may take the following as the composition of the cold blast cast iron No. 1. of this country.

| | |
|---|---|
| Iron, (with a little manganese) | 21 atoms. |
| Carbon, . . . | 4 — |
| Silicon, . . . | 1 atom. |
| Aluminum, . . . | 1 — |

The mean specific gravity of such iron is 6·703.

The same chemist, from the mean of five analyses of hot blast cast iron No. 1, constructs the following table of the constitution of such iron.

| | | | Atoms. | |
|---|---|---|---|---|
| Iron, | 95·584 | that is, | 27·31 | $\left.\right\} = 6\frac{1}{2}$ |
| Manganese, | 0·871 | — | 0·249 | |
| Carbon, | 2·099 | — | 2·79 | $\left.\right\} = 1.$ |
| Silicon, | 1·086 | — | 1·086 | |
| Aluminum, | 0·422 | — | 0·337 | |

that is, $6\frac{1}{2}$ atoms of iron and manganese to 1 atom of carbon, silicon, and aluminum ; and here the carbon, silicon and aluminum, are very nearly in the proportions of 12, 5 and 2, instead of 4, 1, 1, as found in the cold blast cast iron. The mean specific gravity of all the specimens analyzed was 7·062, whereas that of cold blast iron is 6·703.

From this then it appears that iron smelted by the hot blast has its specific gravity increased by about the 22nd part, and that it contains a greater amount of pure iron in the proportion of 13 to 7.

| | Iron. | Carbon, &c. |
|---|---|---|
| For cold blast cast iron, No. 1, has | $3\frac{1}{2}$ atoms | 1 atom. |
| hot blast, do. No. 1, — | $6\frac{1}{2}$ — | 1 — |

Hot blast iron is therefore purer than cold blast iron.

Immediately on hot blast cast iron being brought into use, it was observed that there was a difference in its mechanical properties when compared with iron manufactured by the cold blast and the current opinion was that smelting by the hot blast detracted from the strength of the iron. Numerous and elaborate sets of experiments undertaken by Messrs Hodgkinson and Fairbairn of Manchester, at the request of the British Association, lead in general to an opposite conclusion. The following table contains a general summary of the results obtained by Mr Hodgkinson in respect to the direct strength of the irons prepared by the two modes as regards compression and extension. The second column shows the force in pounds which is necessary to crush a cylinder whose transverse section is a square inch ; the third column gives the force in pounds which is required to tear asunder such a cylinder ; and the ratios of these forces are shown in the fourth column.

| Description of Metal. | | | Compressive force per square inch in lbs. | Tensile force per square inch in lbs. | Ratio. |
|---|---|---|---|---|---|
| Devon Iron, | No. 3, | Hot blast, | 145,435 | 21,907 | 6·638 to 1 |
| Buffery Iron, | No. 1, | Hot blast, | 86,397 | 13,434 | 6·431 to 1 |
| Ditto, | No. 1, | Cold blast, | 93,385 | 17,466 | 5·346 to 1 |
| Coed-Talon Iron, | No. 2, | Hot blast, | 82,734 | 16,676 | 4·961 to 1 |
| Ditto, | No. 2, | Cold blast, | 81,770 | 18,955 | 4·337 to 1 |
| Carron Iron, | No. 2, | Hot blast, | 108,540 | 13,505 | 8·037 to 1 |
| Ditto, | No. 2, | Cold blast, | 106,375 | 16,683 | 6·376 to 1 |
| Carron Iron, | No. 3, | Hot blast, | 133,440 | 17,755 | 7·515 to 1 |
| Ditto, | No. 3, | Cold blast, | 115,442 | 14,200 | 8·129 to 1 |

From this table it appears that the resistance of cast iron to rupture by extension varies from 6 to 9 tons upon the square inch, while its resistance to rupture by compression varies from 36 to 65 tons. It further appears, that the absolute strength of some irons, both as regards their tenacity and their power of resisting compression, is considerably increased by the hot blast. This remark, indeed, applies to all the specimens named in the table, except the Buffery, No. 1. The greater strength of the hot blast iron of Carron over the cold blast iron of the same works, is particularly remarkable : the additional power of No. 3 to resist compression is no less than 8 tons on the square inch, and its tenacity is augmented by $1\frac{1}{2}$ tons on the same sectional surface.

It would, however, be hasty to conclude at once from this table that the hot blast irons are superior in every respect to those manufactured by the cold blast. The following table, exhibiting a general summary of the experiments upon the transverse strength of the two sorts of iron, present some modifying considerations.

| Description of Metal. | | Ratio of strength, that of the cold blast being represented by 1000. | Ratio of powers to sustain impact, that of the cold blast being represented by 1000. |
|---|---|---|---|
| Carron Iron, | No. 2, | 1000 : 990 | 1000 : 1005 |
| Devon Iron, | No. 3, | 1000 : 1417 | 1000 : 2786 |
| Buffery Iron, | No. 2, | 1000 : 931 | 1000 : 962 |
| Coed-Talon Iron, | No. 2, | 1000 : 1007 | 1000 : 1234 |
| Coed-Talon Iron, | No. 3, | 1000 : 927 | 1000 : 925 |
| Elsicar and Milton Iron, | No. | 1000 : 818 | 1000 : 875 |
| Carron Iron, | No. 3, | 1000 : 1181 | 1000 : 1201 |
| Muirkirk Iron, | No. 1, | 1000 : 927 | 1000 : 823 |
| | Mean, | 1000 : 1025 | 1000 : 1226 |

This table then shows that the strength of hot blast iron to resist transverse strain is greater than that of cold blast iron in the

ratio of 1025 to 1000, and that its strength to resist impact is greater in the proportion of 1226 to 1000; but it will be observed that the extraordinary difference of the Devon No. 3 iron, in a great measure accounts for the difference in strengths as shown in the mean results.

Mr Fairbairn has also instituted a series of experiments on the effects of permanent weights in deflecting bars of the two sorts of iron. Five bars of cold and five of hot blast Coed-Talon No. 2 iron, one inch square, were selected, and loaded with different weights, the ends being supported on props 4½ feet asunder, and left in this position to determine how long they would sustain the loads without breaking. The ultimatum of the experiments may be far distant. Mr Fairbairn remarks that if we may judge from the hardihood displayed by the bars in resisting the load, there is every probability of the experiment outliving tho experimenter. But at the end of fifteen months from the institution of the experiment, he was able to state the mean increase of deflection of the bars at $\frac{66}{1000}$ inch for the cold blast, and $\frac{69}{1000}$ inch for the hot blast, giving the ratio of 1000 to 1045.

Mr F. in his report remarks that there cannot be a doubt of the force of cohesion being strongly developed in these experiments. The minute crystalline particles of the bars are acted upon by loads which in the heavier weights (448 lbs.), are almost sufficient to produce fracture; yet fracture (except in one instance) has not been produced, and to what extent the power of resistance may yet be carried, is left for time to determine. It nevertheless appears from the present state of the bars (which indicate a slow but progressive increase of deflections), that we must at some period arrive at a point beyond their bearing powers; or otherwise to that position which indicates a correct adjustment of the particles in equilibrium with the load. Which of these two points we have in this instance attained, is difficult to determine; sufficient data are however attained to show that the weights are considerably beyond the elastic limit,* and that cast iron will support loads to a much greater extent than what has usually been considered safe, or beyond that point where a permanent set takes place. But in whatever way this may be determined, it is obvious that these experiments give greater indications of strength than has generally been supposed cast iron would do; and should the bars continue to support the loads for a few years longer, there cannot exist a doubt as to the security of this metal under applications hitherto unknown; and the same may be said of other materials.

It was also found as might be expected that temperature exercises a considerable influence on the strength of cast iron. The mean of the experiments on this point gave as the strength of

Cold blast iron at 26° and at 190° in the ratio of 874 to 743.
Hot blast iron at 26° and at 190° ———— of 811 to 731.

being a diminution in strength as 100 to 85 for the cold blast, and as 100 to 90 for the hot blast; or 15 per cent. loss of strength in the cold blast, and 10 per cent. in the hot blast.

The conclusion at which Mr Hodgkinson arrives, and to which Mr Fairbairn may be held to assent, is stated in that gentleman's report as follows:—

"Beginning with No. 1 iron, of which we have a specimen from Buffery Iron Works, a few miles from Birmingham, we find the cold blast somewhat surpassing the hot blast in all the following particulars:—direct tensile strength, compressive strength, transverse strength, power to resist impact, modulus of elasticity (stiffness), specific gravity, whilst the only numerical advantage possessed by the hot blast iron is that it bends a little more than the cold blast iron before it breaks.

"In the irons of No. 2, the case seems in some degree different; in these the advantages of the rival kinds seem to be more nearly balanced. They are still however rather in favour of the cold blast. Referring to No. 2 iron, from the Carron Works in Scotland, we find the tensile, compressive, and transverse strengths, together with the modulus of elasticity and specific gravity all higher in the cold blast than in the hot blast; whilst the ultimate deflection and power of sustaining impact are greater in the hot blast. The cold blast iron is the better, but the difference is very small. In the No. 2, from the Coed-Talon works in North Wales, the tensile strength is greater in the cold blast than in the hot; but the resistance to compression is higher in the latter than in the former, and that is the case with the specific gravity.

"So far as my experiments have proceeded, the irons of No. 1, have been deteriorated by the hot blast; those of No. 2, appear also to have been slightly injured by it; whilst the irons of No. 3, seem to have been benefited by it. The Carron Iron, No. 3, hot blast, resists both tension and compression with considerably more energy than that made with cold blast; and the No. 3, hot blast-iron, from the Devon Works in Scotland, is one of the strongest cast irons I have seen; whilst that made with the cold blast is comparatively weak, though its specific gravity is very high, and higher than the hot.

"From the evidence here brought forward, it is rendered exceedingly probable that the introduction of the hot blast into the manufacture of cast iron, has injured the softer irons whilst it has frequently mollified and improved those of a harder nature; and considering the small deterioration that the irons of the quality No. 2, have sustained, and the apparent benefit to those of No. 3, together with the great saving effected by the heated blast, there seems good reason for the process becoming as general as it has done."

The great extent of the experiments on which this opinion is based, and the care manifested in conducting them, together with the undoubted impartiality of the experimenters, induce us to assent to it, notwithstanding many particular cases which have seemed to us to bear an interpretation more in favour of irons manufactured with heated air, and notwithstanding what we might have been led to expect from the greater purity of the hot blast irons.

Taking the rival irons however at par as regards their mechanical values, the expense of the modes of manufacture is such as to warrant us in believing the introduction of the hot blast to be one of the greatest improvements of recent years. This we think is clear upon theoretical grounds, but we may in the first place inspect the facts of the case.

When iron is smelted by the cold blast, the coal is previously converted into coke, by which process it loses rather more than half its weight. The matter driven off by coking constitutes a most important part of the fuel, as coal-gas and other inflammable products. When the hot blast is employed, coking is not necessary, but leaving the expense of coking out of consideration, the materials employed (and consequently the expense incurred) in producing a ton of iron stand as follows:—

At the Clyde Iron Works, near Glasgow, in 1829, when the combustion was effected by the cold air blast, there were consumed

| | Coals. tons. | cwt. | lbs. |
|---|---|---|---|
| For smelting, 3 tons of coke equal to . | 6 | 13 | 0 |
| For the blowing engine, . . . . | 1 | 0 | 7 |
| Total coal per ton of iron, | 7 | 13 | 7 |
| Limestone, . . . | 0 | 10 | 56 |

In 1831, with the hot blast at 450° F., coke being still used for smelting, there were consumed,

| | | | |
|---|---|---|---|
| For smelting, 1 ton 18 cwts. of coke, equal to | 4 | 6 | 0 |
| For heating the air . . . . | 0 | 5 | 0 |
| For the blowing engine, . . . . | 0 | 7 | 4 |
| Total coal per ton of iron, | 4 | 18 | 4 |
| Limestone, . . | 0 | 9 | 0 |

In 1833, with the hot blast at 612° F., raw coal alone being used, there were consumed

| | tons. | cwts. | lbs. |
|---|---|---|---|
| For smelting, . . | 2 | 0 | 0 |
| For heating the air, . | 0 | 8 | 0 |
| For the blowing engine, | 0 | 11 | 2 |
| Total coal per ton of iron, | 2 | 19 | 2 |
| Limestone, . . . | 0 | 7 | 0 |

Between these years, the daily quantity of iron from a furnace was increased from 6 to 9 tons, and the expense reduced from £4 per ton, to £2 12*s*.

The registers of other works exhibit nearly the same results.

* The *elastic limit* is that point where bodies under strain lose the power to restore themselves when the load is removed; a property which is strongly exemplified in cast iron. It has been considered by many that materials cannot be loaded with safety beyond that point.

At Calder works, the consumption has diminished in the proportion of 7 tons 17 cwt., to 2 tons 2 cwt.; and the limestone is diminished from 13 to 5½ cwt. At the Codner Park and Buttery Works in Derbyshire, each furnace in 1829 turned out about 29 tons of iron weekly. They were worked of course with coke, and blown with cold air. Each ton of iron required for its production 6 tons, 16½ cwt. of coal made into coke, and 17½ cwt. of limestone. By the introduction of the hot blast, the same furnaces turn out each 49 tons of cast iron; and every ton of iron requires for its production only 3 tons of coal (not made into coke) and 15½ cwt. of limestone.

These facts, which might be considerably extended, sufficiently establish the advantage in point of economy of the hot over the cold blast. As to the actual saving, it of course varies in every work, according to the nature of the coal, and the care with which the operation is conducted. The way in which the heated air acts is very obvious. When a forced stream of air is employed for combustion, the resulting temperature must evidently be affected by the temperature of the air injected; for the air introduced must be brought up to the heat of the furnace when this has attained a state of equilibrium; and the colder it is when introduced, the more heat will be expended in effecting that object. But this is not all. The heat developed in common cases of combustion by cold air is distributed in three portions: one is communicated to the burning fuel; another is carried off with the volatile products, and a third remains to operate upon any surrounding matter to be afterwards dissipated by wider diffusion. By this distribution, there is a nearly equal temperature all over the interior of the fireplace. When the air is forced into the fire in a strong current, the oxygen of it, or that element which supports the combustion, is brought more immediately into contact with the burning fuel, and there is a certain degree of concentration around that point. This does not appear to arise solely from the circumstance of more air being forced into the fire—for in the case of an open fire, there is an unlimited supply—it seems to depend more on the assistance given by the mechanical force to the chemical affinities, whose action gives rise to combustion. By blowing a common fire with a pair of bellows, we force successively a quantity of the cold air into contact with the ignited coals, and thereby raise its temperature more rapidly than it would otherwise be raised; and the effect is a corresponding increase of the affinity of its oxygen for the oxidizable materials of the fire. A more rapid combination is thus effected, and the heat is more concentrated. But the same effect would be brought about in a much more remarkable degree, were the air forced into the fire at a temperature 600° higher, for its affinity would be increased in a corresponding ratio, and this amount of heat would not remain to be supplied after its introduction into the fire.

This explains at once the action of the hot blast in the smelting of iron ores. By heating the air forced into the furnace to 612° or thereby, the whole oxygen combines with the fuel immediately on its entering the furnace, whereas the oxygen of the air of the cold blast does not all unite immediately with the fuel: a large portion of it makes its way upwards through the furnace, producing a scattered heat which is of no use in smelting the iron, though it consumes much of the fuel. By the immediate combination of the oxygen of the hot blast, the heat is concentrated at the bottom of the furnace, and of course subjects the ore at that point to a more intense reducing action, than when diffused among a greater mass of materials. This accounts for the smaller amount of fuel necessary by the hot blast process than by the other; for there is little combustion of fuel beyond what produces an actual effect in the reducing process. It also accounts for the smaller quantity of limestone necessary for separating the clay: for the more intense the heat, the smaller is the quantity of flux required for the fusion of clay. And hence also the greater rapidity of the process; and consequently, the additional quantity of cast iron obtained from a furnace in a given time.

This is the explanation suggested by Dr Thomson in his report to the British Association on the composition of cast iron; and there cannot be a doubt, but that it is the correct one. It may be objected by those who are aware of the fact, that by the cold blast process, the furnaces work better in winter than in summer, turn out more iron, and require both less fuel and lime. The same holds true to a small extent in the hot blast process, and yet the air is heated during both seasons to the same temperature. The idea imbodied in the objection here stated actually led at one time to the practical blunder of cooling the air, instead of heating it before it was introduced into the furnace. The explanation of the apparent anomaly has however no reference to the temperature of the air; but to its hygrometrical state. Moisture is injurious to all forms of the process,* and the warm air of summer contains more moisture than the cold air of winter: were both equally dry, the furnaces would undoubtedly work better in summer by the cold blast process, than in winter, by all the difference of temperature. Indeed the drying of the air before blowing it into the furnace, was made the subject of direct and successful experiment at the Clyde Iron Works, and I believe elsewhere, before the invention of the hot blast process.

## COAL FIELDS OF GREAT BRITAIN.

### CHAPTER II.

#### UPPER COAL SERIES OF LANARKSHIRE.

In the former article we described the nature of the substances which constitute the upper coal formation of Scotland, and promised to give a more particular account of the various workable strata of coal and ironstone in the present. This formation which is quite conformable with the older members of our coal series, is included in a basin which terminates on the west, in the city of Glasgow, and on the east, at Leven seat, near Wilsontown Iron works, a distance of 20 miles. The basin extends north to south from Garnkirk to Carluke, a distance of 15 miles. The whole basin, exclusive of those portions which are occupied by trap and by red sandstone, of such thickness as to place the coals too deep to be workable, includes a space of about 140 square miles, the area of a fresh-water lake during the period of carboniferous deposition.

The upper series contains from 20 to 30 seams of coal of various thickness; five or six of these, however, are all that have ever been wrought in one pit. These seams may be divided into the upper and the lower.

The upper contains five workable seams of coal, namely:—

1st. The upper or ell.
2nd. The pyot shaw.
3rd. The main.
4th. The humph.
5th. The splint.

The first coal varies much in thickness: near Glasgow it is four feet six inches; in Old and New Monkland, it varies from 2½ to 3½ feet. In the parishes of Hamilton and Carluke it is 10 feet thick. The following sections, the one made near the south-eastern extremity of the basin, and the other at the north-western, will afford an idea of the nature and extent of the formation and thicknesses of the workable coals: the two points are distant 18 miles.

*Section of the Law and Chapel Coal Fields.*

| | Feet. | Inches. |
|---|---|---|
| Freestone, | 21 | 0 |
| Shale, | 6 | 0 |
| Upper coal, | 10 | 0 |
| Soft shale, | 1 | 0 |
| Freestone, | 12 | 0 |
| Shale, | 16 | 0 |
| Coal, | 1 | 0 |
| Freestone and shale, | 39 | 0 |
| Coal, | 2 | 0 |
| Grey faikes, | 7 | 0 |
| Freestone and faikes, | 20 | 0 |
| Freestone, | 5 | 0 |
| Main coal, | 5 | 0 |
| Faikes, | 6 | 0 |
| Hard Sandstone, | 1 | 6 |
| Freestone, | 12 | 0 |
| Mud bed, | 0 | 6 |
| Faikes, | 2 | 0 |

* The individual who planned the practical blunder of blowing steam into the furnace, appears not to have been aware of this fact.—Ed.

| | Feet. | Inches. |
|---|---|---|
| Soft shale, | 22 | 0 |
| Freestone, | 18 | 0 |
| Shale, | 4 | 0 |
| Splint coal, | 6 | 6 |
| Wild coal, | 1 | 6 |

*Section of the Rutherglen Coal Field, near Glasgow, from a bore.*

| | Feet. | Inches. |
|---|---|---|
| Earth and olay, | 12 | 0 |
| White Sandstone, | 18 | 0 |
| Shale with plies, | 18 | 6 |
| Shale, | 16 | 0 |
| Shingle, | 0 | 6 |
| 1st or Upper coal, | 4 | 6 |
| Shale with plies, | 6 | 0 |
| Hard Sandstone, | 16 | 0 |
| Coal, | 1 | 0 |
| Shale, | 10 | 0 |
| 2nd Coal, | 5 | 0 |
| Shale, | 20 | 0 |
| Mussel or marble band, | 1 | 6 |
| Shale, | 8 | 0 |
| Sandstone, | 2 | 8 |
| Shale with ironstone plies, | 32 | 0 |
| 3rd or Main coal, | 6 | 0 |
| Shale, | 47 | 6 |
| Hard Stone, | 0 | 8 |
| 4th or Humph Coal, | 3 | 0 |
| Shale, | 1 | 4 |
| Sandstone, | 6 | 0 |
| Ironstone, | 0 | 10 |
| 5th or Splint Coal, | 3 | 6 |
| Shale, | 3 | 0 |
| Coal, | 1 | 6 |

The coals in the above sections are generally pretty uniform in quality, but vary in thickness, throughout the basin. In some places, however, one or more of them are bad and unworkable, from the presence of a whinstone bed, which occurs in connexion with the formation in the parishes of Old and New Monkland. The splint and humph are the coals usually injured in this manner. They are either cubical or splint, or an admixture of the two: none of them are of a caking quality. The splint and humph, which however is only wrought at Govan, are the best for smelting iron. Smithy coal is obtained near Airdrie from the splint coal when affected by the whinstone.

The under portion of the upper coal series contains, near Glasgow, 13 or 14 seams, only one of which is thick enough to be workable; it is three feet thick, the rest are from 12 to 18 inches in thickness. At Airdrie, this portion of the series contains three workable seams :—

| | | |
|---|---|---|
| 1st. The Virtue well Coal, | - | $2\frac{1}{2}$ feet. |
| 2nd. The Kiltongue Coal, - | - | 4 do. |
| 3rd. The Drumgray Coal, - | - | 2 do. |

The distances between these seams are very variable, as also their thicknesses. The first at Calderbraes, measures 2 feet or more; the second and third 2 feet 6 inches each, and situated at distances of six or seven fathoms from each other. The following section shows the condition of this portion of the series to the south of the basin.

*Section of Minerals below the Splint Coal at Castlehill, near Carluke.*

| | Feet. | Inches. |
|---|---|---|
| Faikes, | 8 | 0 |
| Freestone, | 5 | 6 |
| Shale, | 3 | 8 |
| Bituminous shale, with 3 inches of ironstone, | 4 | 3 |
| Musselband ironstone, | 0 | 10 |
| Fire clay, | 6 | 4 |
| Coal, | 0 | 5 |
| Fire clay, | 17 | 0 |
| Shale and ironstone, | 1 | 2 |
| Bituminous shale, | 0 | 10 |
| Ironstone, | 0 | 6 |
| Fire clay, | 10 | 4 |
| Hard rock, | 0 | 6 |
| Soft shale, | 2 | 8 |
| Fire clay, | 1 | 9 |
| Shale, | 0 | 5 |
| Coal, | 3 | 8 |
| Fire clay, | 5 | 0 |
| Freestone, | 0 | 6 |
| Fire clay, | 6 | 0 |
| Bituminous shale, | 1 | 2 |
| Fire clay, | 2 | 6 |
| Dark freestone, | 4 | 0 |
| Shale, | 1 | 6 |
| Dark freestone, | 1 | 6 |
| Hard do. | 15 | 6 |
| Coal, | 0 | 10 |
| White freestone, | 7 | 0 |
| Shale, | 1 | 0 |
| Ironstone, | 0 | $1\frac{1}{2}$ |
| Bituminous shale | 1 | 0 |
| Ironstone, | 0 | 4 |
| Coal, | 1 | 9 |
| Fire clay, | 6 | 6 |
| Faikes, | 0 | 4 |
| Clay shale, | 3 | 6 |
| Freestone, | 1 | 6 |
| Faikes, | 9 | 0 |
| Freestone, | 1 | 2 |
| Clay shale, | 2 | 0 |
| Bituminous shale, | 1 | 0 |
| Fire clay, | 2 | 0 |
| Freestone, | 40 | 8 |
| Shale, | 0 | 8 |
| Coal, | 4 | 3 |
| Blue faikes, | 38 | 0 |
| Grey faikes, | 3 | 7 |
| Dark do. | 3 | 6 |
| Grey do. | 1 | 0 |
| Dark do. | 2 | 0 |
| Shale, | 6 | 0 |
| Grey faikes, | 1 | 6 |
| Shale, | 2 | 8 |
| Coal, | 2 | 6 |
| Bituminous shale, | 0 | 2 |
| Grey faikes, | 1 | 4 |
| White freestone, | 9 | 0 |
| Faikes, | 16 | 5 |
| Ironstone, | 0 | 2 |
| Shale, | 1 | 11 |
| Fire clay, | 0 | 8 |
| Faikes, | 1 | 6 |
| Fire clay, | 1 | 9 |
| Faikes, | 18 | 2 |
| Shale, with 4 inches ironstone, | 4 | 0 |
| Coal, | 1 | 6 |
| Fire clay, | 0 | 7 |
| Faikes, | 15 | 6 |
| Coal, | 0 | 6 |
| Faikes, | 22 | 6 |
| Shale, | 3 | 8 |
| Shale, with 3 bands of ironstone, 7 in. | 4 | 6 |
| Bituminous shale, with 4 inches of ironstone, | 2 | 3 |
| Faikes and freestone, | 11 | 0 |
| White freestone, | 25 | 0 |
| Shale, | 1 | 8 |
| Coal, | 0 | 1 |
| Fire clay, | 4 | 0 |
| Bituminous shale, with 4 inches of ironstone, | 4 | 5 |
| Coal, | 2 | 0 |
| Fire clay, | 2 | 2 |
| Faikes, | 16 | 11 |
| Freestone. | 30 | 0 |
| Clay Shale, | 1 | 8 |
| Bituminous shale, | 0 | 4 |
| Black band ironstone, | 0 | 10 |

Below this there is no stratum which has been wrought of either coal or ironstone, except a bed of kidneyshaped balls, known by the name of the curly balls. There has also recently been discovered a four feet coal; but it has not been sunk to, so that its quality is in a great measure unknown.

The reader by this time is furnished with a general idea of the nature, depth, and extent of the upper series of the coal formation of Lanarkshire. This in a treatise of this nature is all that can be given, as the section at each place is somewhat different from the section of the same portion of the stratification at another.

*Ironstones.*—The first ironstone occurs 24 fathoms above the Ell coal of the Monklands; it measures from 12 to 14 inches thick. It is a blackband ironstone. It is wrought at present only in the estate of Carnbro by the Carnbro Iron company; but has also been found in the lands of Woodhall: a pit recently sunk at Carnbrœ through a portion of an upper red sandstone, to the depth of 96 fathoms, passes through both this ironstone and the Airdrie blackband, and the whole coals we have enumerated, as overlying the Airdrie blackband ironstone. This is the only instance where the two bands have been found in the same winning. The upper ironstone abounds with the remains of Ganoid (1) fishes, among which are the Palæoniscus (2), the Megalicthys (3) Hebbertii, and the Gyracanthus (4) of Agassiz. It also abounds with several varieties of fresh water unios, and the remains of plants, particularly calamites and lepododendra. These plants are singularly converted into cubical coal.

The next ironstone that claims our notice is the celebrated Airdrie blackband; as already mentioned, this band lies from 14 to 16 fathoms below the splint coal: it measures generally about 18 inches in thickness. The only places in which it has hitherto been wrought, are in the parishes of Old and New Monkland: but it has been recently found in Skellyton, near Larkhall, four miles from Hamilton, where it is said to measure nearly two feet in thickness. The following Iron works are principally supplied with the ironstone of this stratum:—Govan, 5 furnaces; Clyde, 6; Gartsherrie, 16; Summerlee, 6; Dundyvan, 8; Calder, 8; Carnbro, 8; Monkland, 5; Cleland, 1; in all, 63 furnaces, each manufacturing, when in blast, from 90 to 100 tons of pig iron per week. It requires nearly three tons of raw ironstone to manufacture one ton of iron; it must thus be evident, that a very great quantity of the raw material is consumed annually, and that the present source of supply must become exhausted ere many years have passed away; yet such is the abundance possessed of this mineral by some of the present Iron masters, that they have sold large fields of it, one obtaining £110,000 for a field of not more than 280 acres; and another, £18,000 for the sub-lease of a small portion of the ironstone in the Airdrie estate, which draws £12,000 a-year for its ironstone alone. Withal, it is probable that the blackband will be exhausted in less than 30 or 40 years.

The next ironstone is one four feet thick, which lies a few feet below the Airdrie blackband, at Airdrie hill: it does not occur in any other locality that we know of: it is of inferior quality to the stratum above it. Another blackband occurs at Calderbraes, near Airdrie, between the 1st and 2nd coal, below the splint: it is attended by a layer of cannel coal. The ironstone is about 10 inches in thickness: it is used by the Monkland company only. The next blackband is, perhaps, that last mentioned, in the Castle-hill section. It is wrought in the neighbourhood of Langrig, in the parish of Whitburn. It is nearly of the same quality and thickness as the Airdrie blackband. It is used by the following Iron works:—Shotts, 3 furnaces; Coltness, 4; Castlehill, 2; Wilsontown, 1.

These works also use clay ironstone, found in the lower portion of the upper coal series, and in the lower coal series.

*Musselband Ironstones.*—These are no way valuable in an economical point of view, but are deeply interesting as exhibiting the condition of animal life, during the coal era; and as indicating the contemporaneous origin of certain beds of coal in places remote from each other. These musselbands, as they are not improperly called, consist of the carbonate of iron and the exuviæ of extinct fresh water molluscæ of the genus unio. We have detected eight or nine different species: the largest occur in the lower beds. These shells have not yet been classified by any fossil conchologist. The shells in these bands lie in the most confused manner, but generally in a horizontal position. The first we know of lie about 12 fathoms above the Ell coal. The second occur between the pyat shaw and the main coal this is the Cumbuslang marble. The next occur between the splint coal and the Airdrie blackband ironstone; and the next above the Cleland laigh coal, the second workable seam of the lower portion of the series. Another occurs in connexion with the Shotts' cannel coal. We are not aware of any other. These bands, like the ironstones, containing besides the remains of molluscæ, the teeth and scales of fishes; but we have never observed any plants.

The remains of vegetables occur in some places in great profusion. Among these calamites, (plants allied to the equisitaceæ or horse-tails,) sigillaria, lepododendra, asterophyllites, and stigmaria, particularly the last, are found most plentifully: these are also common to the lower coal series, but the shells are not; none of them occur in it: the shells are all different, and of marine genera.

☞ (1) Ganoid or ganoidal, from the Greek word *ganos*, signifying splendour, applied to a class of fishes, furnished with regular angular thick scales, externally enamelled; these and the placoidian fishes, which were irregularly covered with large or small plates or points of enamel, like the rays or sharks, according to Professor Agassiz, are the only fishes which existed prior to the chalk formation. Of the ganoidians, fifty extinct genera have been recognised. (2) Palæoniscus, a small ganoidian fish found with the Megalicthys. (3) Megalicthys, from *megas*, great, and *ichthys*, a fish. This fish is supposed to have been 60 feet in length: it was originally discovered in the limestone of Burdie house, near Edinburgh, by Dr. Hilbert. (4) Gyracanthus, from *gyros*, round, and *acanthus*, a spine, or thorn. The gyracanthus, like the dog-fish (acanthus spinax), was furnished with elevating dorsal rays, which served to raise the back fin.

## HISTORY.

### CHAPTER III.

#### CHRONOLOGY.

Any person in the habit of attending criminal trials must have been struck with how much depended upon accuracy in ascertaining the precise moment of time at which each of the facts deponed to by the witnesses occurred. The plea of *alibi;* that is, that at the time the crime was committed, the party accused was at a different place, has rather a bad reputation. It has so often been advanced without foundation in truth, and perjury has been so often detected by its own contradictory nature, that for an accused party to set up the plea of *alibi*, is almost regarded as tantamount to a confession of equivocal character—as a sort of forlorn hope in the way of defence. But this Old Bailey character of the plea of *alibi* is at bottom owing to its satisfactory nature when fairly established. Now, in order to the complete establishment of an *alibi*, it is necessary that a correct note have been taken of time—that the witnesses to the criminal act specify the space of time within which it must have been committed, and corroborate the accuracy of their recollections on this head, by stating the circumstances which led them to be aware of the time at the moment. On the other hand, the depositions of the witnesses called to establish the *alibi* must be most distinct and explicit on the point of time, and they must be prepared to corroborate their accuracy by explanations similar to those advanced on the other side, as to how their attention was aroused to take note of the time at the moment.

But the defence of *alibi* is neither the most curious nor the most important that depends upon accuracy in fixing the precise time at which any event occurred. It was remarked in the last chapter, that one of the most powerful corroborations of any story was its own internal coherence, and that a story might be too self-contradictory to render belief in it possible. If the lapse of time allotted to the occurrence of each incident be such as in the natural course of events is sufficient, it affords a presumption favourable to the accuracy of the story. If the time allotted by witnesses to the occurrence of a series of events, some of them wholly, some in part, and some not at all simultaneous, be found to correspond with the sum of the portions allotted to each by different witnesses, this unforeseen correspondence affords strong presumption of the probity of the witnesses.

Now the business of the student of history is in a manner nothing else than the examination of witnesses. To him, as to the judge or juror, time is an important element, both as an ingredient of the narrative, tending to render it full and consistent, and as a means of detecting discrepancies, or discovering confirmations. But to the student of history, more especially when he extends his inquiries far into the past, obstacles are offered which can scarcely occur to him, who has to deal only with contemporaneous and living evidence. His witnesses are dead; their testimony is on record; but where it is defective, he cannot recall them to complete it. Now, much of our historical materials consists of narrative compiled for a public nowise addicted to scepticism—neither sufficiently credulous to believe what was told without further scrutiny, nor sufficiently indifferent as to abstract truth or falsehood, to be able to enjoy what pleasingly filled up its imagination, without fastidiously inquiring into its accuracy.

Again, in examining living witnesses to some fact, we have to do with men who have one common measure of time. In collating the records of the past, we have to do with men, some accustomed to one mode of measuring time, some to another. In order to compare their statements; in order even to understand these statements aright, it is necessary that we make ourselves acquainted in some measure with the different modes of computing time which have obtained in different ages and countries. It happens as often in history as in a court of justice, that the plea of *alibi* may be advanced and sustained. Actions have been attributed to historical characters, which a comparison of dates may at times enable us to show, that it is physically impossible they could have done. We read of heroic feats performed by one leader, at a time when he must have been sprawling in his cradle, or yet unborn. We read of the beauty of Helen and other heroines of antiquity, kindling men to crime at a period, when, if the rest of their story be true, they must have been "loved for antiquity's sake." But in order to call up the dates which lead us to conclusions like these, it is necessary that we be able to reduce their varying measurements of time to one common standard, in such a manner as money-changers do the different denominations of coins current in various countries.

But this reduction of different measures of time to one common standard has a utility greater than merely enabling us to ascertain or approximate to dates with greater accuracy. Without misleading the reader into shadowy abstractions, let any one ask himself what he means when he speaks of TIME. The word implies an impalpable abstraction; and the futile attempts of the wisest and subtlest intellect to frame a right definition of TIME, would seem to indicate that the difficulty in our present state of existence is insuperable. Of this, however, we may convince ourselves, that the notion which we are in the habit of attaching to the word TIME in our unreflecting minds, is a connexion embracing a great many things which are not time. TIME is that in which a succession of events happens; but events themselves are not time; and succession is a word indicative of the relation in which the events take place, not of anything that has a real independent existence of its own. Yet we have no notion of the lapse of time but what is conveyed to us by the lapse of events. The cobbler in his stall knows that a certain portion of time has elapsed, because the hands before the dial of the clock before him have travelled over a certain portion of its surface. The shepherd in some lonely glen knows that a certain portion of time has elapsed, because the shadow of a crag or tree which some time ago pointed to the west, now points to the east; or because the place of the sun in the sky has changed. From boyhood each of these individuals has been accustomed to note the lapse of time in his own way; and from habit, that which is in itself merely a measure of time has become part and parcel of his conception of time. Nor is it only in the visible figure in which the notion of time is clothed that there is a difference between the two. The attempts of the one to measure out portions of time will be much ruder than those of the other. The cobbler with more precision will calculate by hours and minutes. Now, these different modes of thought upon the subject of time are calculated to have important effects, both upon the moral and intellectual character of the people accustomed to them. Not only therefore does a knowledge of how different people in different countries and in remote ages calculated time, make us more correct in our knowledge of dates; it is necessary, from the effect which different modes of computation has on the appearance of society, to enable us to form more correct notions of the habits and character of a people whose history we may be examining.

Hitherto we have spoken of the different ways in which men conceive notions of time; we must now allude to the essential sameness notwithstanding their diversities in the conception which all of them form of time. It is disputed, whether or not that time is an innate idea? But if we strip the conception we form of time, of all the accessories which form no necessary part of it, it is the counterpart of nothing in external nature which our senses can give us knowledge of. Our conceptions of time seem to be produced by feeling the sequence of impressions by a necessary law of our organization. If this conclusion, supported as it is by the Phrenologists, be correct, then in essentials the conceptions formed by all men of time must be identical. Not only, however, are the conceptions all men form of time essentially the same: the great phenomena of nature which impress upon their minds the conception of its lapses, and which serve them as standards of measurement to estimate and compare its portions, are in the main the same. The endurance of darkness, and the endurance of light, are portions of time marked out by natural phenomena, observable by far the greater portion of the human race. The waxing and waning of the moon are others. The revolutions of the seasons unvarying in their general outline belong also to this class. In all ages and in all countries, the succession of day and night, the succession of new and full moon, the recurrence of spring, summer, and autumn, have been made the means of measuring the lapse of time. Sometimes one of these has at first been adopted, sometimes the other; one nation counts by winters, another by moons; sometimes the number of days in the month has been noted, or the number of months in a year; the month or year has been used as a multiple of the day or month; or the day, or month, has been used as a multiple of the month or year. Advancing in nicety of observation of those heavenly bodies, whose motions, as corresponding with the changes, were naturally inferred to occasion them, men discovered that although twenty-eight days approximated to the time that elapsed between new moon and new moon; and although twelve months nearly corresponded with the annual revolution of the seasons; yet that in neither case was the correspondence perfect. The irregularities hence introduced into their calendars forced them to institute more accurate and comprehensive observations of the heavenly bodies, and to devise methods of calculation which should, within certain limited periods, bring these diverging measures of time again into harmony.

The identity in essentials of the conceptions which men form of time, and the general coincidence of the methods they have devised to measure it, enable us to form a general science of Chronology. The various methods adopted in different countries, and at different periods, to improve this science, and its gradual advance towards perfection, constitute its history. The importance of a general acquaintance with the science of chronology, and its history, to the student of general history, arises out of these considerations:— In all languages in which historical documents are preserved, the names of the great divisions of time are derived from, and relate to the succession of day and night, the succession of new or full moons, and the succession of annual revolutions of the seasons. It would be a fertile source of error, however, to infer, that the name which in any one language, at any one time, designates year, month, or day, corresponds exactly in meaning to the kindred term in any other language, or even it may be in the same language at a different period. According to the time at which any nation set itself to perfect its calendar; according to the devices it hit upon for this purpose, have the exact meaning of month or year varied with that nation from what they were before or from what they were in other nations. There were other sources of discrepancy and misunderstanding. Some nations reckoned their day from nightfall to nightfall; others from daybreak to daybreak; some counted from new moon to new moon; others from full moon to full moon. Some commenced their year with the summer, and others with the winter solstice; others again with the re-appearance of the green herb, or the first appearance of the ear of corn. No one year of a nation starting from one of these points would coincide exactly with that of one starting from another. This, if overlooked, would give rise to essential inaccuracies in attempting to reconcile dates. Again, few nations, at least in old times, have begun to reckon their years from one common period. The years of the Jews and Romans were all reckoned from some different and arbitrary commencement. With all these differ-

ences and their occasions, the student of history must be acquainted, if, in collating the evidence contained in the historical records of different countries, he would avoid being necessarily misled by seeming contradictions, or equally deceptive seeming coincidences. It is therefore necessary, with a view to our future course, to trace a brief outline of as much of the history of chronology, as bears immediately upon that portion of history we intend to run over. For this purpose it will be necessary to anticipate a little.

It is chiefly to the school of Alexandria that we are indebted for the preservation of what we know of the early history of chronology, and for the most important improvements in the science previous to the time of Galileo. A brief sketch therefore of the origin of that school, and of the circumstances by which it came to exert the extensive influence it did, will be the best introduction to a bird's eye view of this portion of chronological history.

On the fourteenth of November, in the 337th year before the birth of Christ, Alexander, commonly called the Great, ascended the throne of Macedon. The territories lying between the Adriatic Gulf and the Black Sea, the peninsula (now called the Morea,) and islands of the Grecian sea, Asia Minor, Syria, Mesopotamia, Persia, (at least the western part,) and Egypt, countries originally inhabited by tribes of different religions, languages and customs, had in the course of time come to be subjected to the mastery either of the Persian or Grecian races. The Persians, a race of mountaineers, organized in clans, and owning one common head, had established a monarchy, ruling over Egypt and all the Asiatic countries I have named. The Greeks, a people each settlement of which governed itself, had spread themselves over the rest of the space indicated, and formed numerous colonies all along the western shores of Asia. Upon the ruins of former dynasties a struggle for ascendancy commenced between these two incompatible races. For a time it was carried on with varying success. The Persian power was more thoroughly organized, and completely kept in hand by one. The Grecian, almost entirely disorganized, was more favourable to the development of the individual character. At last the policy of Philip concentrated in his own hand the resources of Greece. The march of the Grecian auxiliaries of the younger Cyrus into the province of Babylon, and the retreat of the ten thousand under Xenophon, had shown at once the way which led to the heart of the Persian empire, and the superiority of the intelligent discipline of Greece to the unreflecting obedience of the Persian hordes. The ambition of Alexander soon availed himself of this knowledge and of his father's power to which he succeeded. The expedition into Asia was neither devised nor executed by Alexander. It had long been the cherished dream of Grecian ambition. He was the centre round which collected the science and experienced tactics of Greece. His is the name in which it was executed; he was the nucleus of the mighty mass that rolled upon Persia. The graceful energy and ambition of youth rendered him a gratifying object to the imagination, and therefore the expedition has been called his, and attributed to him. He was but an accident; any other of little more than average susceptibility would have effected as much in his place. It was Greece, not Alexander, that overthrew the Persian dynasty. His empire died with him; but until the advent of the mightier Romans, the Greeks remained masters of the East; even subsequent to that event it was Greek intellect that swayed and moulded the minds of men.

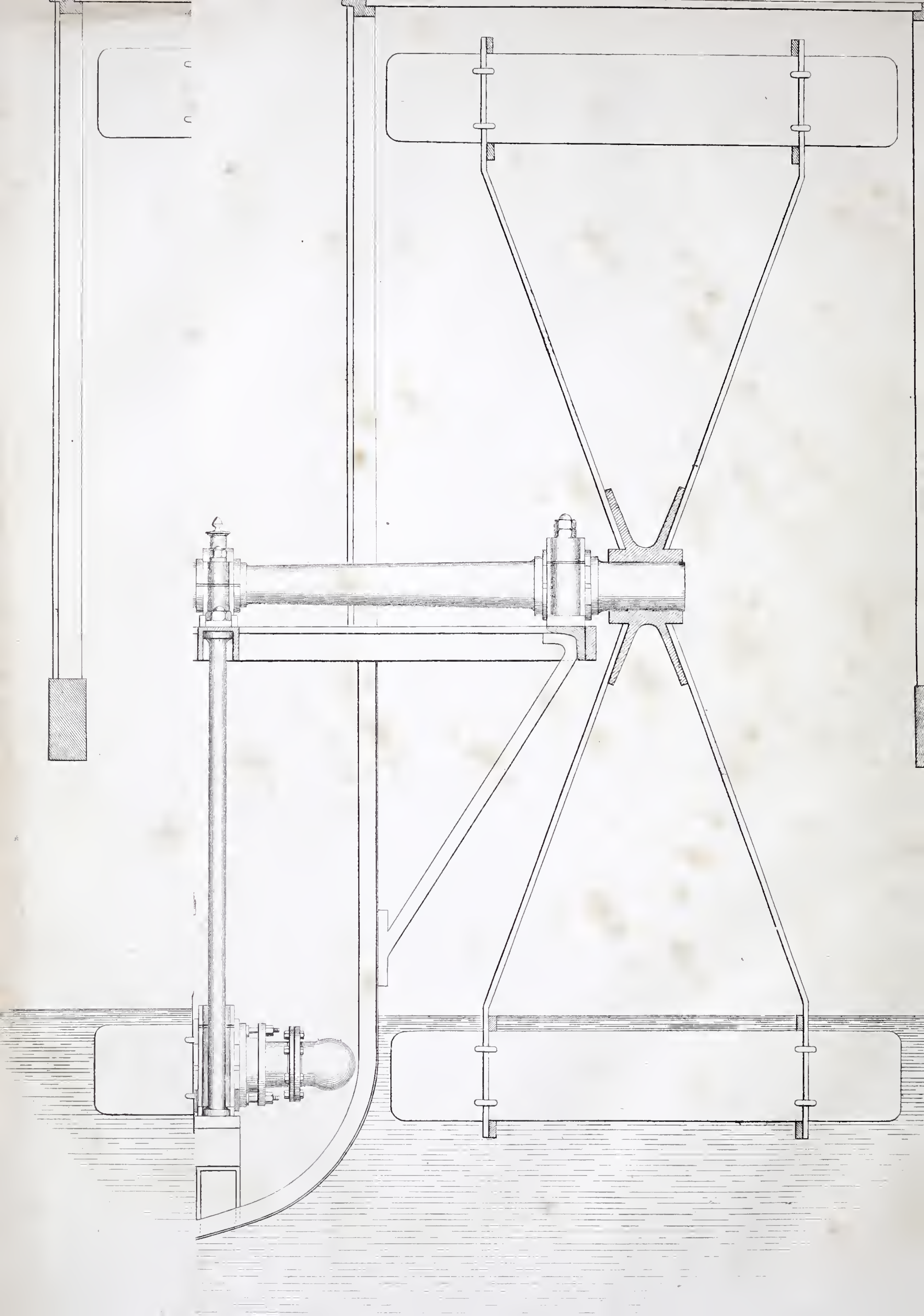
But let the honour of the conquest belong to whom it may, the organization and execution of the assault was masterly. The Greeks after setting firm foot in Asia, advanced along the sea-coast from the Hellespont to the most western mouth of the Nile, subduing and garrisoning every wealthy and powerful seatown in their way. At the extremity of this line they founded Alexandria, a city destined to play a more important part in the annals of mankind than they could have possibly contemplated. They thus determined an extensive but surer basis of operations. In advancing into Asia, they left behind them no power which could not be kept in check by their garrisons. These garrisons had by means of the sea easy communication with Greece and with each other. The invading force now advanced, and one heavy blow dealt on the eastern banks of the Tigris at Arbela, struck down the Persian dynasty never to rise again. The weakness of the bold and generous, but still the boy Alexander, soon displayed himself. The intellect and discipline of Greece had conquered Persia for him; but could not enable him to rule himself. His subsequent life is that of a madman. But Greece was firmly seated on the throne of power, and notwithstanding the feuds among those who after Alexander's death struggled for supremacy among the Greeks, it was still Greeks and none but Greeks who held the reins of power.

Egypt and some adjoining territories fell to the share of by far the most amiable and intelligent of Alexander's associates. Ptolemy Soter was an able general, but he was more; he was a lover of justice, a man of high talents and extensive information, and addicted to literary pursuits. He made Alexandria his capital; he drew scientific men around him; and the intellectual tone of society which he rendered fashionable, combined with the wealth which its admirable commercial position caused to flow thither, was the foundation of the long-enduring prosperity of that city, and the influence it exercised in the world of science and letters. Under him and his immediate successors, Alexandria enjoyed more peace and security than any other country over which the Grecian sway extended, and was the favourite resort of all who lived a life of literary leisure. When a city has thus become the resort of men of letters, there is a sympathetic tone diffused through the whole of its inhabitants: strangers become anxious to visit it, and, pleased with its amenities, settle there. To this and to its wealth is it owing that Alexandria became so long the seat of science and literature. It was not owing to its princes; for after the third generation, they degenerated entirely, and the literary fame of Alexandria continued undepressed even under the mastery of Rome. With the exception of Rome itself, and Athens, none ever approached to it, down to the period when it was overwhelmed by the Mohammedan invasion.

It is in the writings of Ptolemy that we find the materials which, pieced out by incidental and supplementary notices in other writings, put us in condition to establish a tolerably complete and trustworthy history of chronology, as far as our present object is concerned. He records the most important observations of the heavenly bodies previous to his time, stating of course the place of observation, and generally the person by whom it was made. We are thus furnished with the most undoubted evidence as to those places in which during his period of nearly one thousand years, the science of astronomy was cultivated with most effect. The unscientific gossip of writers like Herodotus, Cicero, and the elder Pliny, enable us to add considerably to his information. Scientific treatises, of which the age and authors can be ascertained, and some few monuments, complete the source of this chapter of history. From these by an application of the canons of evidence attempted to be established in chap. ii., may be extracted a history of the chronology of that period. The literature of the subsequent period down to the present day is too plentiful, and too generally known to require its being entered upon. The following brief outline of the results will be found to imbody the most important facts :—

The school of Alexandria took up the science of chronology at the stage to which it had been brought by the Grecians on the one hand, and the Chaldeans on the other. The calendar of Rome was a bungling one originally, and continued to get deeper and deeper in irregularity until reformed by Julius Cæsar, with the assistance of astronomers taught in the school of Alexandria. The Julian calendar has continued to be the calendar of the western world, with a few additions from the Jewish, and some further corrections by Pope Gregory XIII.

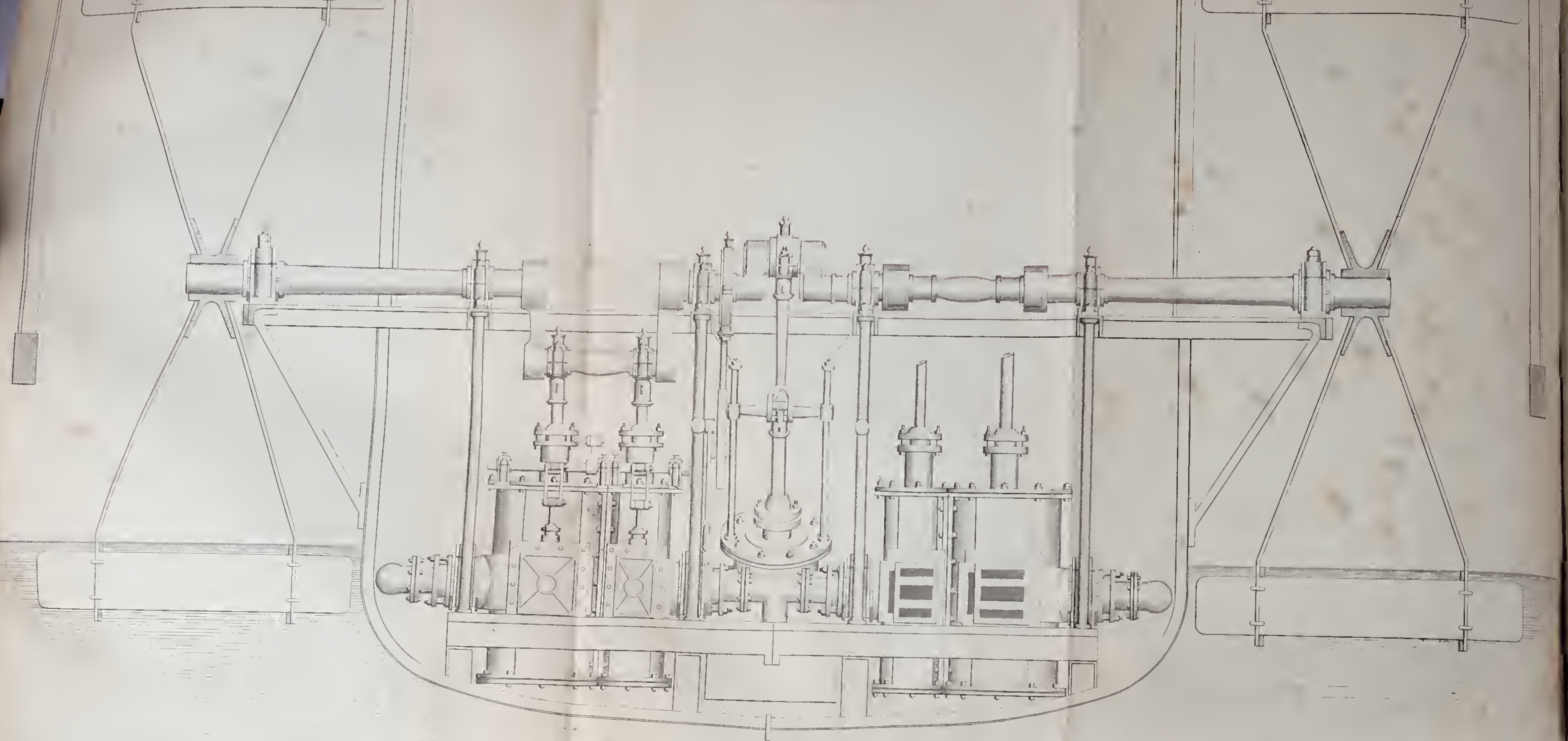
Our information relative to the chronology of the Chaldeans is sufficiently limited. We have no annals of that people. The earliest traces of them in the annals of other people represent them as a broken tribe at the court of a conquering prince. They still exist, however, in the upper Tigris, in scattered communities as an unmixed people, and the frequent notice of their ravages in the Jewish annals bears ample testimony to their warlike propensities. We find them in subjection to the kings of Babylon, and passing in succession under the kingship of the Assyrian, the Mede, and the Persian. Herodotus has informed us, that from the Chaldeans the Greeks learned the art of constructing the pole and gnomon, and the division of the day into hours. Contemporaries of Alexander have recorded the transmission of a series of Chaldean observations to Greece, after the taking of Babylon by Callimachus. Ptolemy cites several eclipses of the sun and moon observed at Babylon by the Chaldeans, and also two comparisons of Mercury, and one of Saturn, with certain fixed stars. The earliest of the eclipses recorded



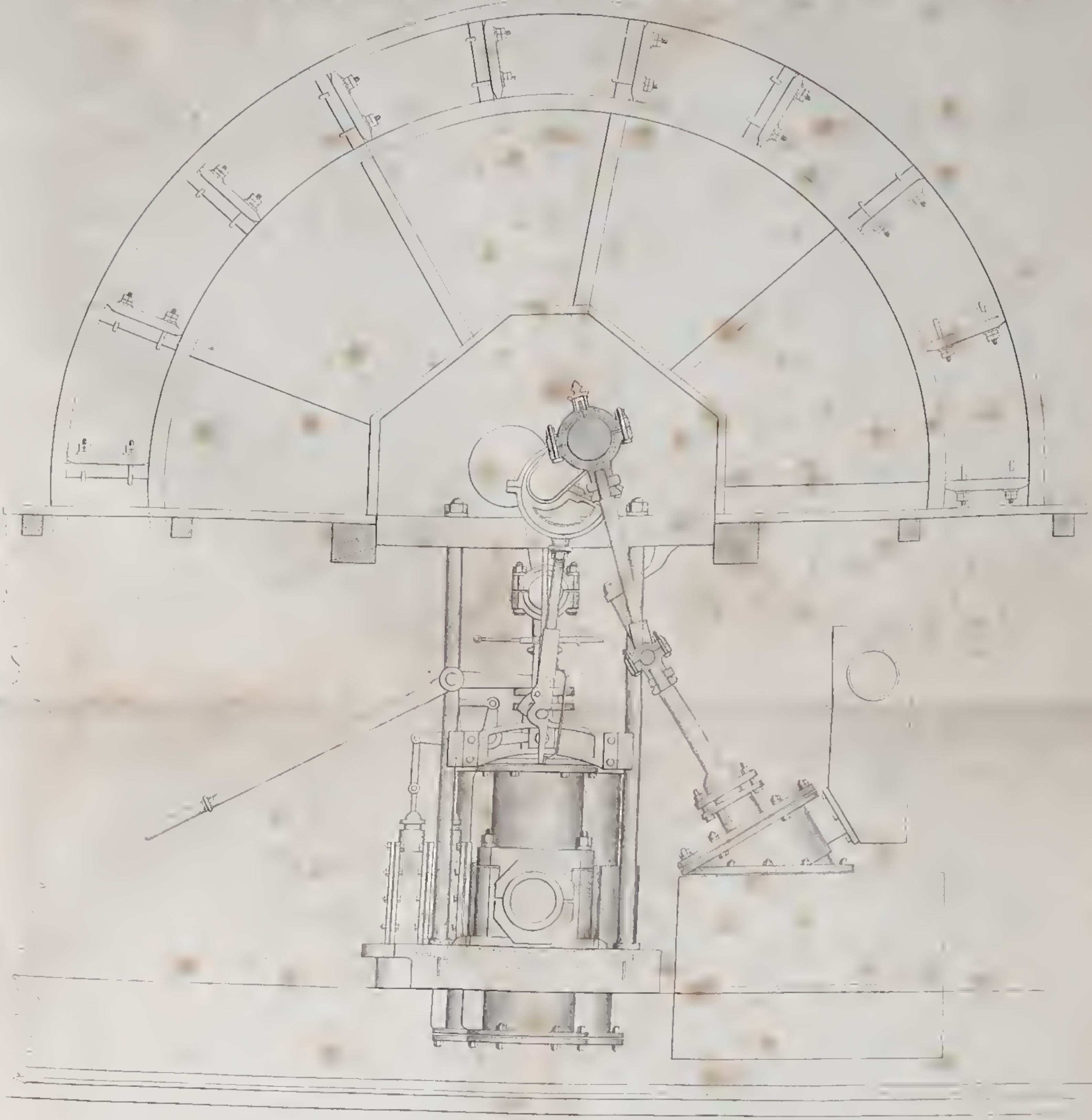
PATENT MARINE ENGINES, FITTED TO THE "EMMET"

BY MESSRS. W. JOYCE & Co.

GREENWICH IRON WORKS.



PATENT MARINE ENGINES, FITTED TO THE "CRICKET" BY MESS.RS JOYCE & C.O GREENWICH IRON WORKS.



is a solar one in the year 721 before Christ; the stellar observations are respectively of the years 245, 237, and 229 before Christ. The era of the Chaldeans was that of Nabonassar, which commenced on the 16th of February, in the year 747 before our era. Of more minute details regarding Chaldean chronology, we have nothing beyond conjecture. The honour of originating and advancing to a high degree of perfection the science of astronomy is theirs beyond a doubt; of their mode of computing time, we can say little more with certainty, than that its era was adopted by the later astronomers of the Alexandrian school.

Previous to the Alexandrine expedition, the advances made by the Greeks in exact chronological knowledge do not seem to have been very great; their observations are comparatively few, and their predictions vague. Solon is recorded to have been the first who ascertained that the lunar month contained less than 30 days. The reform of the calendar he proposed on this account was adopted by the other Greek states. For months of 30 days, he substituted months alternately of 29 and 30 days. An intercalary month of 30 days every two years brought time in accordance with the moon, but put it $7\frac{1}{2}$ days in advance of the sun; this was remedied by the occasional omission of an intercalary month. Meton discovered that 235 synodical months brought back the sun and moon to meet in the same point of the ecliptic, and recommended his cycle of 19 years. It does not seem to have come into use sooner than 400 years before the Christian era, and to have ceased shortly after the Julian reform of the calendar. The method of calculating by Olympiads continued the favourite in Greece in all civil affairs.

The original Roman year was of ten months. These, however, cannot have been lunar months, for the year as far as we can ascertain was solar. They must have been some arbitrary division of time analogous to the nundines, or nine days' market. To Numa is attributed the distribution into 12 months alternately of 31 and 29 days. The intercalations necessary were to be made by the Pontiffs, and they kept the principle upon which it was done a secret. It was no uncommon thing for them to intercalate or not, according as they were desirous of giving an individual who had farmed the public revenue a good or bad bargain. The calendar had gone completely out of order in the time of Julius Cæsar, who reformed it by intercalating two months of 30 days each in the year 707 of the city of Rome, in addition to the intercalary month of the same length, which really belonged to that year. Having thus forcibly brought back the first of January to the time it at present occupies, he divided it into 365 days, arranged in such a manner, that with the aid of one intercalary day in February, every four years, it came much closer to the truth than ever before. It is worthy of remark, that Cicero himself, rather vain of his astronomical knowledge, allowed his prejudice against Julius so far to overcome his better judgment, that hearing some one remark "the morrow the Lyre (the star of that name) rises," he was guilty of the poor joke —"Yes, by special order!"

The Julian became the established calendar throughout the Roman world, and being naturally adopted by the Romish church, was carried by her missionaries over the whole of Europe. A feeling of reverence for the season of the paschal sacrifice as the time of the greater atoning sacrifice, led most to begin the year at that time, instead of the Julian beginning of the first of January. This fixing upon a moveable fast, added to the ignorance of almanac makers, and the error inherent in the Julian calculation again deranged the year. Great dismay was occasioned hereby among the zealous adherents of the Romish church. Lent was visibly and rapidly receding out of the fish months, and how to keep it there became a serious question for a community restrained to fish during the whole of Lent. This is no joke: the inconvenience is first enumerated in various representations to sundry Popes, and urged and expatiated upon with fervid eloquence. At last a great man, Gregory XIII., in the year of our era 1572, took this case of conscience in hand, and by passing over ten days and making some regulations of the calendar, well known to all, bound down the season of Lent, for ever to the fishy months. We may laugh at the good fathers and their anxiety on this head. The Protestants were not a whit behind them in absurdity. Several Protestant cantons in Switzerland refused to receive an alteration emanating from the Romish chair, they were afraid their faith might be contaminated if their calendar was reformed. Protestant Denmark was the last to admit of this Popish innovation, and Protestant England was not much in advance.

From the preceding observations, the student who studies history on a comprehensive plan will see the importance of a strict attention to the science of chronology. The following general data may be useful; but for a knowledge sufficiently perfect to enable him to see his way clearly through the confusion of different systems, he must follow out the subject. We have pointed out the path and cleared the way—it is for him to follow it.

The first year of the Julian era, is the 708th of the city of Rome.

The 46th of the Julian era, and the 754th of Rome, are the first of the Christian era.

The 747th before Christ is the era of Nabonassar—the era of the Chaldean and Alexandrian astronomers.

The era of the city of Rome corresponds with the third year of the sixth Olympiad.

## JOYCE'S PATENT MARINE ENGINES.

*(Illustrated by Drawings of the Engines fitted to the Emmet.)*

The principal novelty introduced by Messrs Joyce in this vessel is the application of Woolf's double cylinders as oscillating engines. The trials hitherto made with these engines, fully prove their superior uniformity of motion over the common species of engine expanding to the same extent. Our Plates, 1 and 2, will sufficiently explain the improvement. Plate 1, being a front elevation of the pair of engines, the piston-rods of one engine being disconnected from the crank, and the valve-chest removed, for the purpose of a better explanation of the construction of the engines. Plate 2 is a side view, showing the position of the air-pump and condenser. The construction of the common Woolf's engine is so generally understood that we need not advert to it, further than to remark that the place of the single cylinder is here usurped by two cylinders of a capacity bearing a direct relation to the extent to which it is intended to expand the steam.

The steam, which is of a higher pressure than is ordinarily used in condensing engines, is first conveyed to the smaller cylinder, whence having exerted its direct pressure upon the piston, it is passed to the larger one where it acts expansively (in conjunction with the vacuum in the condenser) in a degree dependent on the ratio of capacity of the two. In this manner the expansion of steam is carried on, as it were, in a very gradual manner, the joint pressure in the two cylinders being brought to a much greater degree of uniformity than is possible in the common high pressure engine, where the variation in the pressure at the commencement and termination of the stroke is so great as to produce a serious irregularity in slow-motioned engines. Messrs. Joyce have taken advantage of this contrivance in constructing their oscillating marine engines, the result of which is the production of a fast and economical working steamer. The peculiar modification and arrangement of the two cylinders is clearly shown in Plate 1, where it will be seen that they are bolted together face to face, each cylinder being provided with a trunnion, working in bearings fixed to the bottom plate, which trunnions form also the entrance and discharge pipes for the steam to and from the cylinders.

The slide valves are of the common three-ported kind; they are worked by a rocking shaft placed in bearings on the cylinder covers. The pin of the lever, by which the connection with the eccentric is effected, fits into a grooved arc struck from the centre of oscillation attached to the eccentric-rod, which arc slides freely in guides attached to the supporting pillars of the crank shaft. In this manner, the oscillatory motion of the cylinder does not act prejudicially upon the valve, as the eccentric acts equally well in whatever angular position the cylinder may be. The air-pump is worked from a central crank; it is placed in the transverse centre of the vessel, but out of the line of the cylinders, this position being necessary in order to permit of the steam-pipe being placed between them.

The speed of the vessel is stated at 14 miles an hour through the water, and this with a consumption of $4\frac{1}{2}$ lbs. of coal per indicated horse-power (of 66·000) per hour.

## ON THE CONSTRUCTION OF FIRE-PROOF BUILDINGS.

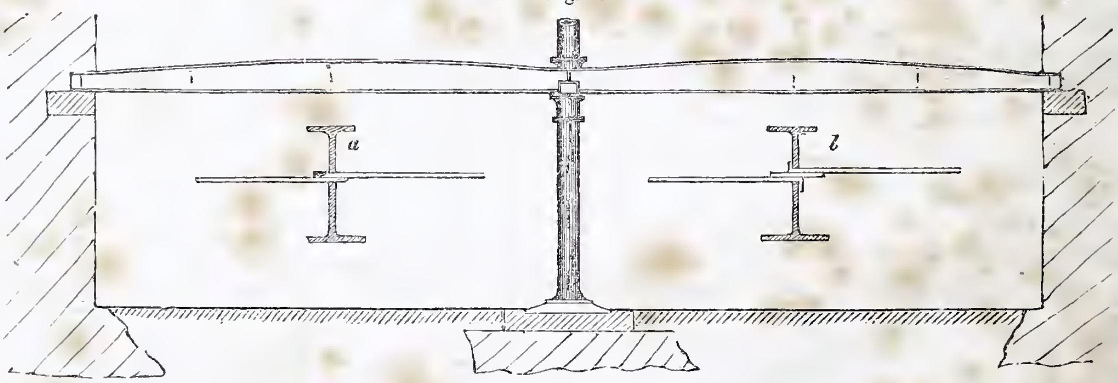
The introduction of fire-proof buildings in the manufacturing districts, has undoubtedly been attended with the happiest results in the preservation of life and property. Their adoption for warehousing goods is of more recent date, but as far as we can yet judge by experience, they have proved equally beneficial for this purpose. The merchants of Liverpool, especially, have been burned into the conviction, that fire-proof warehouses must be an improvement, and in that city their employment for new warehouses is becoming universal. The general principles on which those buildings should be constructed have been clearly enumerated by Mr Fairbairn, in his able Report on the fire-proof warehouses of Liverpool. It is the object of the present paper to enter more minutely into the details of their construction, taking as our guide the practice of Mr Fairbairn and other trust-worthy engineers. But before doing so, we would quote from the Report above cited, the following observations upon the peculiar kind of stability possessed by these structures, as this is a point which must never once be lost sight of in proportioning and fixing the various parts. The Report proceeds—

"There can be no doubt that if a fire-proof building is constructed as it ought to be, it is the most secure in every respect; but on the other hand, if unskilfully or dishonestly constructed, it is of all others the most dangerous. This is owing to the manner in which the lateral pressure of the arched flooring is distributed, so that should a single beam or column be broken or the tye-rods be displaced, the destruction of the whole building is almost inevitable. It does not admit of partial excellencies or defects—it must be either secure or insecure, either skilfully designed and positively right, or unskilfully designed and positively wrong."

1. Pillars.—It has been known for some time that the strongest form in which cast-iron pillars can be made is a hollow cylinder, and accordingly this form is now universally adopted. For pillars of 5 to 6 inches diameter, the thickness of metal should be from $\frac{3}{4}$ to $\frac{7}{8}$ in., and from 8 to 10 in. diameter, 1 in. to $1\frac{1}{8}$ in. thick. From Mr Hodgkinson's recent experiments on the strength of cast-iron pillars, published in the Philosophical Transactions of Manchester for 1840, (and elsewhere), we have the data for calculating their strength with great precision; for example, we find by his tables that a hollow pillar 8 in. diameter, 1 in. thick, and 20 feet long, will support, without flexure, 637 cwt.; the same pillar 16 feet long will support 673 cwt.; and if 12 feet long, 699 cwt., and so on for pillars varying in diameter, thickness, and length It is a point of the utmost importance in fixing the pillars that they shall have a solid bearing at top and bottom, their strength being influenced in an extraordinary degree, according as their ends are shaped.

Thus it was found by experiment that a pillar with both ends terminating in flat discs broke with 9007 lbs.; a pillar of the same dimensions in every respect, but with one end flat and the other turned hemispherically, broke with 6278 lbs.; whilst a third pillar of the same dimensions, but with both ends turned hemispherically, broke with 3017 lbs.—these numbers being nearly in the ratio of 1 : 2 : 3. The ends of the columns are usually shaped, as shown in fig. 1., which represents a side elevation of the beams, showing the position of the tye-rods, &c. The different methods of keying the beams are shown at *a* and *b* of the same figure.

Fig. 1.




2. Beams or Girders.—According to Mr Hodgkinson's valuable experiments on cast-iron beams, the strongest form in which a given weight of metal can be cast is that represented in fig. 2. which is a plan of the beam, the flanges of which taper to each extremity in a parabolic curve. At *d* the ends are made circular, to embrace the head of the column, and at *e* joggles are cast on the end of each beam, and bound with a wrought-iron strap to keep the ends together.

For proportioning these beams, the following may be relied on as a sound practical rule, viz.:—Take the 'breaking weight' at from two to three times the weight estimated to be carried by the beam, then assume the depth of the beam at about $\frac{1}{10}$th part of the distance between the supports (for ordinary cases), and the sectional area of the bottom flange may then be found by the following proportion, viz. as the depth in feet of the beam in the middle is to the distance between the supports in feet, so is one twenty-sixth part of the breaking weight in tons to the sectional area of the bottom flange in square inches. Make the thickness of the bottom flange one-twelfth part of the depth of the beam, and find the breadth by dividing the area by the thickness. Make the area of the top flange one-fifth part of the area of the bottom flange, and half its breadth. Make the thickness of the web of the beam rather more than half the thickness of the bottom flange, for the beam when cast, but the pattern may be made somewhat thinner. It is usual to make the web of all beams under 16 inches in depth, about $\frac{9}{16}$ in. thick in the pattern, as the metal will not run well if thinner. In general, it is recommended to reduce the depth of the beam at the ends to $\frac{2}{3}$rds of the depth in the middle,

and this reduction must be made on the upper side of the beam. But in many cases the beam is preferred to be parallel in depth throughout. In all cases it is advisable to reduce the breadth of the flanges at the ends to one-half their breadth in the middle, and this should be done by a parabolic curve, as by that means the strength of the flange at each point will be exactly proportioned

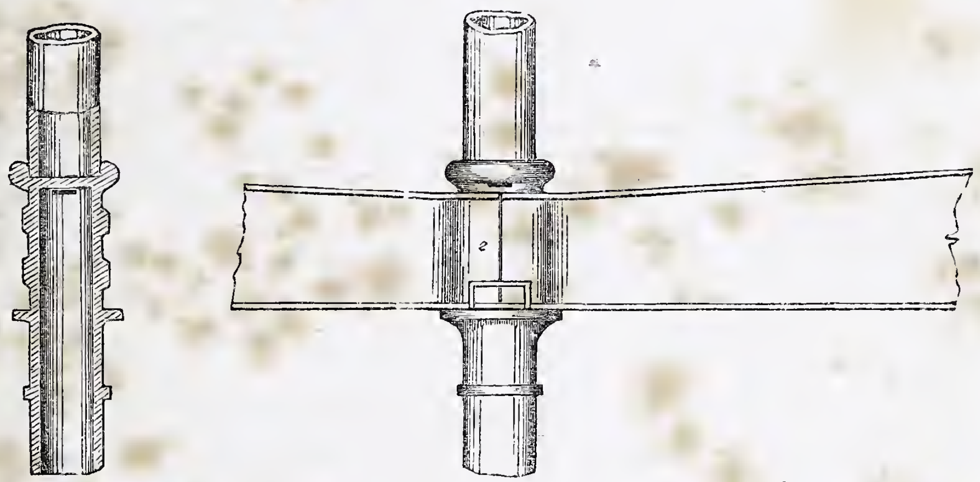
Fig. 2.


to the amount of the strain thrown upon it in a uniformly loaded beam. From the nature of the parabolic curve the lengths of the ordinates vary as the rectangles contained by the segments of the chord cut by the ordinates; but it has been ascertained by experiment that those rectangles are also proportional (in an inverse ratio) to the strength of the beam at those points, hence the breadth of the bottom flange will be a direct proportional to the strength of the beam at each point. By the adoption of these improved forms of beams a saving of about $\frac{1}{3}$d in the weight of material is effected, when compared with the older forms of cast-iron beams which were in use only a few years back. As a general rule for beams of this class, their strength is nearly a proportional of the sectional area of the bottom flange. It was found by experiment that a ┬ beam broken with the flange downwards bore a weight represented by 1000, but when reversed, it only bore 323.

In proportioning the strength of beams, it must be borne in mind, that a load of 10 tons on the centre is equivalent to 20 tons distributed equally over the beam, or to 15 tons placed upon two points, each a third of the length of the beam from the end.

The pattern for such beams should be made $\frac{1}{16}$ inch to the foot, round on the under side, to allow for the drawing of the metal in

Fig. 3.




cooling. The usual manner of fixing and keying the beams is explained in fig. 3, which is an enlarged view of a column and beams. The upper column fits into a bored socket on the head of the under one, which is alse prepared by chipping and filing to receive the ends of the beams, these being fastened together by the straps, already mentioned, round the projections at *e*.

3. Tye-rods.—These act a most important part in a fire-proof building, by tying together the walls and the beams in a species of net-work, and by assisting them to resist the lateral strain, caused by the flat brick arches of the flooring. With this view their obvious position should be near the bottom of the beam where they form the chord of the arc; but as this would be inconvenient, especially in low-floored buildings, from the loss of head-room, it is usual to bury them in the brick-work, keeping them, however, as low as possible, or just at the soffit of the arch. In this position they will generally perforate the neutral axis of the beam, and without injuring its strength, afford sufficient security to the arch. The usual practice in the manufacturing districts is to have 5 lines of $\frac{7}{8}$-inch square rods in a width of 30 feet, two lines being imbedded in the side-walls, and the remainder built into the arches. This is considered perfectly secure for a cotton-mill, but in a warehouse where the floors are much more heavily laden, there should be in the same width seven lines of rods, each $1\frac{1}{4}$ inch square. This will give a sectional area of about 11 square inches in 30 feet, which, taken at 25 tons to the square inch, will give a tensile strength equal to 275 tons. In factories the tensile strength of the tye-rods need not exceed 100 to 110 tons for this width, or nearly 4 tons to the foot, but for warehouses this should not be less than from 9 to 10 tons. Two of the modes in most general use for keying the tye-rods are shown here; it will be remarked, that a line of rods tye the heads of the columns together.

4. Skewbacks.—Into the end walls are built arch-plates of cast-iron, technically called 'skewbacks,' to resist the thrust of the last arch, and they are keyed to the beams in the usual manner. By this means all lateral strain is taken off the end walls, provided the tye-rods have the requisite tensile strength for retaining the beams in their proper positions.

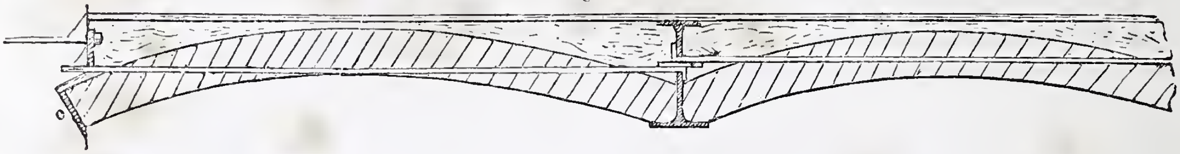
The skewback, as well as the ends of the beams, should be fixed a little higher than their proper level to allow for the settling of the walls, which invariably takes place as the weight increases by their ascent.

The ends of the beams must be bedded either upon hard stone

built into the wall, or on a cast-iron wall-plate, and the ends resting on the columns chipped and filed to insure a perfect bearing; likewise, the ends of the columns where they fit to each other. Fig. 4 is a cross-sectional view of the beams and arched flooring on a larger scale, showing the tye-rods, and the skewback *c*.

5. Arched Flooring.—The arches forming the floor are of brick-

Fig. 4.



work, and stretch between the beams, being supported by, and springing from, the bottom flange of each. The versed sine or rise of the arch should be $1\frac{1}{2}$ inches to the foot of span to insure perfect safety, and in no case should be less than $1\frac{1}{4}$ inches, below which they become positively dangerous. They are generally filled up at the haunches, and levelled with a concrete of lime, sand, and ashes, and the floor laid with flags, slates, or tiles, bedded in mortar. The weight of such a floor, irrespective of the weight of the beams, may be estimated at from 14 to 16 square feet of horizontal surface to the ton, supposing the arches to be about 10 or 12 feet span.

## SYMPTOMS OF INGENUITY MISAPPLIED.

Wonder, in its phrenological sense, is one of the most prominent faculties of the human mind; and accordingly we are not to be surprised that efforts were early made to gratify it. It is to the uneducated workings of this faculty, that we owe some of the most gigantic works of antiquity—pyramids, hanging gardens, labyrinths, and temples and tombs hewn out of rocks. These all bear evidence, that wonder was the actuating principle in the minds of their projectors; and it would be no difficult task to show, that the same mental propensity must have been pre-eminently active among any people that could submit to be taxed for the execution of such undertakings. It has been said that such works argue advancement in civilization—we deny the inference. A structure uselessly great, and having no other peculiarity than magnitude, if it proves any thing, proves the barbarism of the people to whom it belongs. The idea of cutting a mountain into a statue is a barbarous idea, and so is that of a human figure bestriding the Hellespont. The Egyptians—at least the builders of the Egyptian pyramids—were a barbarous people, and their great Memnon offers nothing towards a palliation of the charge. Even the celebrated tower of Belus proves no more real advancement in civilization, than the rude Druidical cairn.

But we also find the same faculty which manifests its operation in the production of what is huge, and associated with what it calls the "*sublime* in art," descending into the other extreme, and feeding itself upon

——— ideas so minutely delicate,
As would famish great souls to look at.

As it descends, it loses however its distinct character; it calls into action, faculties of a more and more intellectual kind; and uniting with them, the result of the combination, is some contrivance more calculated to astonish by its ingenuity, than by its dimensions. It is at this point that true mechanical genius comes into action; and although it may expend its powers upon what is really in itself of no value, even when the end answers expectation, its efforts mark a positive advancement—a first real step towards utility. Man however is an imitating, as well as a wondering animal, and accordingly his earliest mechanical efforts—after he had provided himself rudely with implements for the common purposes of life, and for the destruction of his enemies—seem to have been directed to the production of mechanisms which should imitate his own movements, and the movements and actions of inferior creatures—he would in fact be a creator, and infuse vitality into his imitations. But as this is a degree of advancement at least symptomatic of ingenuity, and forming as it does the twilight which ushered in the broad and triumphant day which has opened upon the mechanical world, it may be interesting to glance shortly at the progress of this special department of contrivance.

The first notice which we have of machinery imitating the arbitrary and spontaneous motions of living beings, is handed down to us by Homer. The blind bard informs us that Vulcan fabricated tripods for the banqueting hall of the gods, which advanced of their own accord to the table, and again returned to their place, moving on living wheels, instinct with spirit. Vulcan however was not a mere mortal blacksmith, nor was Homer a very good judge in mechanical matters; we shall therefore say nothing more on the subject of these convenient stools, except that they appear not to have been confined to the banqueting hall of the gods; for the philosophical Aristotle mentions self-moving tripods, and the equally sagacious Apollonius saw and admired similar pieces of mechanism among the sages of India.

The next inventions of the kind—and they appear to have surpassed even the tripods of the celestial Vulcan—are the self-moving statues of Dædalus. Callistratus, the tutor of Demosthenes, informs us that these statues received their motion from the mechanical powers, and so active were they, that according to Plato, Aristotle and some others, it was necessary to tie them to prevent their running away. Beckmann however questions this, and states that they differed only from the statues of the ancient Greeks and Egyptians, in having their eyes open, and their feet and hands free, and that the reclining posture of some, and the attitude of others, as if ready to walk, gave rise to the exaggeration that they possessed the powers of locomotion. But if this opinion is to be maintained in the particular case of Dædalus, we are bound to apply it to all others which rest upon similar testimony, and thereby to exclude the claims of the ancients entirely to the rank of inventors.

Archytas of Tarentum, who flourished about 400 years before the commencement of the Christian era, adds to his renown as a truly wise man, a great mathematician, statesman and general, the reputation of having constructed a wooden pigeon, which was "animated by a concealed spirit," and could fly. Archimedes has also the reputation of having constructed similar automata; but of these, we have no account. And indeed the claims of the ancients to the character of mechanicians, appear upon the whole to be very slender; for we find nothing farther of any merit which can be ascribed to them. Descending to modern times, the water-clock presented to Charlemagne by Harun al Raschid, was really a curious and ingenious piece of mechanism for the time. In the dial-plate, there were twelve small doors corresponding to the hours, which were indicated by the opening of these doors to let out little metallic balls which struck the hour, by falling upon a brazen bell. The doors continued open till twelve o'clock, when twelve little knights mounted on horseback, came out at the same instant, and after parading round the dial, returned to their apartments, and shut the doors behind them. In the thirteenth century, Albert, bishop of Ratisbon, spent thirty years in constructing a human figure, which advanced to the door when any one knocked, opened it, and saluted the visitor; about the same time friar Bacon was engaged in constructing his brazen head—in which, however, we have very little faith. During the next century, the celebrated John Muller,

better known as Regiomontanus, made a wooden eagle in imitation of the wooden pigeon of Archytas. The eagle is reported to have flown to meet the emperor Maximilian, when he arrived at Nuremberg, on the 7th June, 1470. After saluting him like a good loyal subject, the sagacious bird flew back to the gate of the city, and perching upon it, waited the emperor's approach. This may be thought rather too much for a wooden eagle ; but it must be borne in mind that it is a *fact* of history. It is also on record, that when the emperor approached the gate, the eagle stretched out its wings, inclined its body, with all the other indications of becoming respect for so great an emperor. It is reported also, that the author of the wooden eagle further improved his tools and made an iron fly, which could fly from his hand round the room, and return again to its master.

Charles V. abdicated his throne, and amused himself in his later years with automata of various kinds. Figures of armed men and horses, some beating drums, others playing upon flutes, and a greater number attacking each other with spears, were very commonly introduced upon the table after dinner. These were sometimes changed for wooden sparrows, which could make the circuit of the room on wing, and deposit themselves in their nests. The same illustrious mechanic is reported also to have made corn-mills, so exceedingly small, that they could be concealed in a glove, yet so powerful that they could grind in a day as much corn as would supply eight men with food for a day! He ought, undoubtedly, to have taken a patent for the invention, and set up as a millwright.

A toy constructed by Camus, for Louis XIV., when a child, was highly celebrated at the time. It consisted of a small coach drawn by two horses, and which contained the figure of a lady within, and a footman and page behind, and a driver in front. When placed on a table of the proper size, the coachman smacked his whip, the horses moved their legs naturally, and when the carriage arrived opposite the king's seat, it stopped; the page stepped down and opened the door; the lady alighted, and with a curtsy presented a petition which she held in her hand to Louis. After waiting some time, she again curtsied and re-entered the carriage; the page closed the door, and having resumed his seat behind, the coachman whipped the horses, and drove on. The footman, who had likewise alighted, ran after the carriage and jumped up behind into his proper place. This was certainly a toy, such as a king might play with.

The genius of Degennes, a French officer, better known as having defended the colony of St Christopher against the English forces, took a higher flight, and he contrived to perform by wheels and pinions, the functions of living organism. He constructed a peacock which could walk about as if alive, peck up grains of corn from the ground, and digest them as if they had been subjected to the action of the stomach. It was probably this automaton which suggested to Vaucanson, the idea of constructing his famous duck, considered by some the most ingenious piece of mechanism that ever was made. This wonderful duck exactly resembled the living animal in size and appearance, executed all its movements, ate and drank with avidity, muddled in the water, and cried *quack—quack*—in the most natural manner. It was, moreover, anatomically correct in its construction: the wings, the viscera, and every bone of the living duck were exactly copied in the automaton, and every part performed its proper movements. Digestion was a chemical not a mechanical process, as in the peacock of Degennes. Beckmann informs us that when he saw it, the machinery was somewhat deranged, but it was still able to eat, drink, and move. Its ribs were made of wire and covered with ducks' feathers, and the motion was communicated through the feet by means of a cylinder, and fine chains like those of a watch.

The same mechanist invented several other surprising automata, among which were the flute-player, and the pipe and tabor-player. These admirable specimens of ingenuity, wherever they were exhibited, produced the greatest sensation. The body of the flute-player was about five feet six inches high, and placed upon a piece of rock surrounding a pedestal $4\frac{1}{2}$ feet high by $3\frac{1}{2}$ feet wide. This pedestal contained six pair of bellows, and the machinery by which they were worked. The air passed into the body of the figure by three tubes, and its passage outwards through the mouth was regulated by valves worked by levers, so perfectly adjusted, that the performances of the figure were generally allowed to surpass in execution those of all living performers on the flute. The pipe and tabor-player was considered by the artist himself a more ingenious piece of workmanship than even his duck ; and indeed such were the difficulties he experienced in the construction of this automaton, that he was frequently on the point of abandoning it in despair. His patience and his fertile genius however prevailed, and his automaton acquired the reputation of being the best performer on the flageolet and tambourine in Europe.

In constructing this machine, M. Vaucanson was led to remark that the flageolet must be the most fatiguing of all musical instruments to the human lungs, in consequence of the vastly different and rapidly changing efforts which the muscles of the chest must make during the performance. This pressure he found for the highest notes to be fifty-six pounds, whereas a single ounce was more than sufficient for the lowest.

Ingenious as these pieces of mechanism are, they were supposed to sink into entire insignificance on the appearance of the famous chess-player of M. Kempelen. As this, however, is now generally admitted to have owed more to collusion than to mechanical invention, it has hardly any claims to be regarded as a true automaton, and ought not to be mentioned in comparison with the machines of Vaucanson. Indeed, the inventor himself distinctly stated, " that the machine was a *bagatelle*, which was not without merit in point of mechanism, but that the effects of it appeared so marvellous, only from the boldness of the conception, and the fortunate choice of the methods adopted for promoting the illusion." The real chess-player indeed was a living one ; and the machinery was simply the means employed to deceive the spectators as to the presence of the flesh and blood performer. The speaking machine of the artist was however a more honest attempt ; and, in fact, it and the attempts of Kratzenstein and Willis to produce a talking automaton, and the discoveries of Savart respecting the mechanism of the human voice, possess too great an interest to be satisfactorily described in the space which we could at present devote to them.

The automata of the two brothers Droz have been much admired. One of these, a singing-bird, three-quarters of an inch in length, is described by Mr Collinson as sending out a " clear melodious song, sufficiently strong to fill a room of thirty feet square with its harmony." The father, M. Le Droz, had before executed some equally admirable pieces of mechanism. One of these was a clock presented to the king of Spain, which among other curiosities had a sheep that imitated perfectly the bleating of a living one ; and a dog watching a basket of fruit, that barked and snarled when any one offered to take it away. Mr Collinson also describes a drawing automaton constructed by the brothers. It was the figure of a man as large as life. " It held in its hand a metal style, and when a card of Dutch vellum was laid under it, and a spring touched, which released the internal clock-work from its stop, the figure immediately began to draw. * * * After one card was finished, the figure rested. I put a second and third, and so on to five separate cards, all different subjects, and these seemed to be the extent of its delineating powers. The first card contained, I may truly say, elegant portraits of the king and queen facing each other ; and it was curious to observe with what precision the figure lifted up its pencil in the transition of it from one point of the draft to another, without the least slur ; for instance, in passing from the forehead to the eye, nose, and chin, or from the waving curls of the hair to the ears, &c. I have the cards now by me, &c."

It was in imitation of the singing-bird of M. Le Droz that the Swiss, Maillardet, constructed the humming-bird which was exhibited in the principal towns of Britain some forty years ago. The same artist has since exhibited a writing and drawing figure ; a tumbling figure, which performed many surprising evolutions about a horizontal wire ; a steel spider, resembling a living one, and which crept all over the table ; a hissing serpent, and a musical lady which could perform eighteen tunes on the piano-forte in the most natural way, and with all the appearance of feeling the effect of the music which her own fingers produced : the bosom heaved, the eyes moved as if under the control of the liveliest feeling. This is rather more, we suspect, than can be said for nine-tenths of flesh and blood figures which " attempt the piano." The most popular of Maillardet's automata is the magician. The figure, dressed in the costume of the old magicians, appears seated at the bottom of a wall, holding a wand in one hand and a book in the other. Twenty questions, ready prepared, are inscribed upon as many oval medallions, and a spectator selecting any of these, the medallion is placed in a

drawer ready to receive it. The drawer then shuts, and the magician rises from his seat, bows his head, describes circles with his wand, and gravely consults the book as if in deep thought. After appearing to ponder over the question for some time, he raises his wand, and striking the wall with it, two folding doors fly open, and display an appropriate answer to the question. If the medallion had no question inscribed on it, the magician simply shakes its head; but if there be two questions on the medal, he answers them in succession.

We have now become so familiar with the automatic machinery employed in our manufactories, that mechanisms of this description have in a great measure lost their interest; and, it must be admitted, that surprising as they may appear even to scientific spectators, the astonishment speedily wears off, and they cease even to amuse. The passion for them which existed in the 18th century, however, had its beneficial effect, in showing the accuracy which might be attained by nice adjustment and execution of parts, and certainly facilitated in some measure the introduction of that delicate machinery which is now so successfully applied in several departments of the arts. As Sir David Brewster remarks on this subject—" The same combination of the mechanical powers which made the spider crawl, or which waved the tiny rod of the magician, contributed in future years to purposes of higher import. Those wheels and pinions, which almost eluded our senses by their minuteness, reappeared in the stupendous mechanism of our spinning-machines, and our steam-engines. The elements of the tumbling puppet were revived in the chronometer, which now conducts our navy through the ocean; and the shapeless wheel which directed the hand of the drawing automaton has served, in the present age, to guide the movements of the tambouring engine. Those mechanical wonders, which in one century enriched only the conjurer who used them, contributed in another to augment the wealth of the nation; and those automatic toys, which once amused the vulgar, are now employed in extending the power and promoting the civilization of our species. In whatever way, indeed, the power of genius may invent or combine, and to whatever low or even ludicrous purposes that invention or combination may be originally applied, society receives a gift which it can never lose; and though the value of the seed may not be at once recognised, and though it may lie long unproductive in the ungenial till of human knowledge, it will some time or other evolve its germ, and yield to mankind its natural and abundant harvest."

# NATURAL PHILOSOPHY AND CHEMISTRY.

## CHAPTER V.

HEAT OF COMPOSITION—SPECIFIC HEAT—LATENT HEAT—EFFECTS OF HEAT—LIQUEFACTION—VAPORIZATION.

We have hitherto considered heat in a state of freedom, and susceptible of being estimated by our sensations and the thermometer. Heat thus developed, may be termed the heat of temperature. But we have now to consider it in relation to different species of matter, and under circumstances where it enters as it were into the composition of bodies, losing its character of temperature, and becoming insensible to our feelings and our instruments.

*Specific heat.*—When equal bulks of the same liquid, at different temperatures, are mixed together, the resulting temperature is the mean of the two. A pint of water at 150°, being mixed quickly with a pint at 50°, a thermometer immersed in the mixture, will indicate a temperature of 100°; that is, the half of 150°+50°. In this experiment, the pint of water at 150° loses 50° of heat, and the water at 50° acquires an equal amount. But if we substitute for the cold water, an equal measure of mercury at 50°, and agitate it with a pint of water at 150°, the temperature of the mixture will not be 100°, but 118°. While the temperature of the mercury is raised from 50° to 118°, or 68°, that of the water is lowered only 32°, or not quite half as much. This shows that to obtaining a mixture of mercury and water which shall have the mean temperature, we must employ 68 measures of the mercury, and 32 of the water or quantities nearly in the ratio of 2 to 1; and all forms of the experiment lead to the same conclusion. It therefore follows, that the same quantity which is required to raise the temperature of one measure of water any given number of degrees, will raise that of two measures of mercury as many degrees; or what is the same thing, the quantity of heat which is required to elevate the temperature of a pint of water *one* degree, will be fully sufficient to elevate the temperature of an equal measure of mercury *two* degrees. In other words, mercury possesses only half the heat of equally hot water, and this is expressed by saying, that water has twice the *capacity* for heat that mercury possesses.

As all bodies are not liquid, it is found to be more convenient to compare their capacities for heat in reference to equal weights, rather than equal volumes. If we thus compare water and mercury, we find that a pound of water takes thirty times more heat than a pound of mercury, to elevate its temperature the same number of degrees: the capacity of water therefore, viewed in this way, is to that of mercury as 30 to 1, which is the same thing as 1000 to 33⅓. Similarly, if a pound of pure copper be heated in an oil bath to 300°, and be then immersed in a pound of water at 50°, the copper will give out its excess of heat to the water, and both will arrive at a temperature of 72°. But in the establishment of this equilibrium of temperature, it is to be remarked that the copper loses 228°, and the water gains only 22°: the capacities therefore of water and copper for heat are in the relation of those numbers, which are nearly as 10 to 1, and almost accurately as 1000 to 96½.

In thus examining the capacities of bodies for heat, it is convenient to have a standard of comparison; and as water is a liquid with which every one is familiar, it has been adopted in preference to all other substances. But as it is merely the relations of the capacities which we attempt to express, it is obvious that we may call the standard capacity by any number we please. Accordingly it is sometimes taken as 1, and at other times it is expressed by 1000. This last enables us to dispense with fractions, and to employ the notation of whole numbers; and for this reason we prefer adopting it here. Thus taking the capacity of water as = 1000, the capacities of mercury and copper are expressed by 33 and 96. These numbers are called the *specific heats* of the bodies, and signify the proportional quantities of heat which the bodies respectively absorb or give out, in having their temperatures equally altered.

The experiments selected for examples, although they point out very clearly the meaning of the term specific heat, point out only one method, and that perhaps not the best, by which the specific heat of bodies may be determined. It is liable to error from the vessel, in which the mixture is made, absorbing a portion of the heat; and from the mixture requiring a little time to make, some portion of the heat is dissipated before the equilibrium of temperature is established. In skilful hands it is however susceptible of great accuracy, and has yielded results of the highest value to science. But the most exact method consists in allowing the substances experimented upon, to cool the same number of degrees under precisely the same circumstances—to enclose them, for instance, in a highly polished metallic vessel, containing the bulb of a thermometer in its centre, and to place the vessel under the exhausted receiver of an air-pump. The *time* which the different substances take to cool, expresses the relative quantities of heat which they respectively give out, and this is what we understand by specific heats. Thus, if we have two bodies heated to 300°, and find that when circumstanced alike, the one requires 30 minutes to cool down to 50°, and the other

only 15, the quantities of heat which they respectively part with, that is their specific heats, are in the relation of 30 to 15, or 2 to 1. This is the method adopted by Dulong and Petit in their admirable experiments on the specific heats of bodies. It required all their ingenuity to ensure accuracy; but all their results may be verified approximately by employing instead of a silver vessel, one of bright tin, and instead of placing it under the receiver of an air-pump, it may be set aside in a room in which there is no remarkable current of air. The experiment, moreover, may be reversed. If two bright tin vessels, one containing a pound of water, and the other a pound of oil, be exposed equally to heat in front of a strong fire, the temperature of the oil will be found to rise two degrees for every degree that the temperature of the water is elevated. And again, when removed from the fire and placed under precisely equal circumstances to cool, the oil will be found to descend to the temperature of the surrounding medium in half the time which the water requires. Both of these forms of the experiment show that the specific heat of oil is only half that of water.

These methods have been applied to the determination of the specific heats of a great number of different substances, the most important of which are given in the following table, (mostly from Regnault.)

| | | | |
|---|---|---|---|
| Water . . . . | 1000 | Steel, . . . . | 118 |
| Alcohol, . . . . | 660 | Iron, . . . . | 114 |
| Sulphuric acid, . | 333 | Tin, . . . . | 109 |
| Nitric acid, . | 442 | Copper, . . . . | 95 |
| Oil of turpentine, . | 426 | Lead, . . . . | 31 |
| Sulphur, . . . . | 202 | Silver, . . . . | 81 |
| Charcoal, . . . | 241 | Bismuth, . . . | 51 |
| Phosphorus, . . | 189 | Antimony, . . | 56 |
| Iodine, . . | 54 | Platinum, . . . | 59 |
| Arsenic, . . . . | 81 | Gold, . . . . | 32 |
| Marble, . . . | 205 | Mercury, . . . | 33 |
| Glass, . . . . | 177 | Zinc, . . . . | 101 |
| Common salt, . | 225 | Nickel, . . . . | 109 |
| Brass, . . . . | 94 | Cobalt, . . . . | 107 |

The method of cooling, adopted in the experiments of Dulong and Petit, gives results so exact as to show that the capacities of bodies for heat increase as their temperatures rise; so that it requires more heat to raise them a given number of degrees when at a high than when at a low temperature. The capacity of iron, for instance, when tried at temperatures up to 212° is 110; up to 392° it is 115, up to 572° it is 122, and up to 662° it is 126. The capacity of the other bodies in the table has been found similarly to increase with the temperature, and seems to bear a discoverable relation to the increasing rate of expansion.

Dulong and Petit have likewise established a relation between the capacity for heat of simple bodies, and the proportion by weight in which they combine with oxygen and other substances (chemically), and Nauman and Avogadro have extended the law to compound bodies. This is a subject which will be again adverted to, but in the mean time one example may be given. Sulphur and zinc combine chemically in the comparative numbers of 16 and 32 (neglecting fractions); that is to say, the ultimate atom of sulphur weighs just half as much as the ultimate atom of zinc,—a pound of it will therefore contain twice as many atoms as a pound of zinc. Now the law established by Dulong and Petit is, that for every ultimate atom—no matter of what substance—the same quantity of heat is required to produce in a mass of the atoms a given change of temperature. The sulphur ought therefore to take just twice as much as the zinc—weight for weight—and by consulting the table we observe that this is correct; for the specific heat of the sulphur is 202, and that of zinc is 101.

The determination of the specific heat of gases is a problem of great practical difficulty. It has engaged much attention; but from the extreme delicacy of the processes necessary, and the small quantity of material contained in a large volume of the gas, the results are not of that certain character which render repetition unnecessary. Some chemists—as Delarive and Marcet—have endeavoured to show that the specific heats of all gases are the same for equal volumes; but Dulong and Apjohn have controverted this opinion, and it is now generally admitted that more reliance is to be placed upon the old experiments of Delaroche and Berard than upon any others which have since been published. Their method consisted in transmitting known quantities of the gases, heated to 212°, in a uniform current, through a serpentine tube, surrounded by water in a vessel, and noting the temperature of the water at the beginning and end of the experiment. Their results are as follow, taking the specific heat of water = 1000.

| | | | |
|---|---|---|---|
| Atmospheric air, . | 267 | Nitrous oxide gas, . | 237 |
| Hydrogen, . . | 3294 | Olefiant gas, . . | 421 |
| Carbonic acid, . . | 221 | Carbonic oxide gas, | 288 |
| Oxygen, . . | 236 | Aqueous vapour or steam, | 847 |
| Nitrogen, . . . | 275 | | |

The capacity of bodies for heat is very materially affected by their density: whenever density is diminished, capacity for heat is increased and *vice versâ*. When the volume of a gas is doubled—by withdrawing half the pressure upon it—its specific heat is *nearly* doubled. An equal amount of compression is attended with an equal but opposite effect. This explains why a thermometer suspended under the receiver of an air-pump has its temperature lowered some degrees during exhaustion; and it is one reason why the air on the top of a high mountain is so much colder than that on the plain at its base. The converse explains why air suddenly compressed to one-fifth of its volume by a piston in a small brass cylinder evolves so much heat as to cause the ignition of tinder, or other readily inflammable substance, immersed in it. A jet of hot steam issuing suddenly under great pressure, into the atmosphere, instead of burning a hand held into it, gives a sensation of cold. If water contained in a tube be held in a current of atmospheric air, (any gas) issuing under a similar pressure, it will speedily be frozen; and if the compressed air contain any aqueous vapour, it will be converted into snow as it issues out. Common coal gas, which may be described as a solution of charcoal in hydrogen gas, when first highly compressed to expel heat, and then allowed suddenly to expand, is so cooled, that the charcoal is separated like a black cloud, and deposits itself just as the snow which is formed when compressed air saturated with watery vapour, is allowed suddenly to expand.

When spirit of wine and water are mixed together in equal measures, it may be shown that the mixture is more dense than the mean density of the liquids, for there is a diminution of volume, and the consequence is, a diminution of specific heat; the temperature becomes sensibly warm. In the same way when equal weights of water and sulphuric acid (vitriol), are mixed together, the specific heat of the mixture should be, provided there were no chemical action, $\frac{1000 \times 333}{2} = 666$ (nearly) but the real capacity of the mixture is found to be only 587. The excess therefore, that is, $666 - 587 = 79$, becomes free, and shows itself by raising the temperature of the mixture; and accordingly, on mixing together sulphuric acid and water, it is well known that a temperature higher than that of boiling water may be produced. It was even supposed at one time, when heat was looked upon as being a positive substance which combined with bodies in different proportions, that the absolute quantity of heat which a body contained, might be determined by such an experiment, thus: if the rise of temperature produced by 79 of heat becoming free, is expressed by 180° above 32°; then the quantity of heat which remains behind, must be greater than that in the proportion of 587 to 79; and hence is equivalent to $\frac{587}{79} \times 180° = 1337\frac{1}{2}°$, and this at the temperature of $-1305\frac{1}{2}°$ of Fahrenheit's scale, a body should contain no heat at all; it should be the absolute zero. But no two such experiments ever give the same result; and it is evident from the fact of the specific heat diminishing as the temperature sinks, that the term at which the two quantities should vanish, must be infinitely remote, and that there is not such a thing as an absolute zero at all. In fact, the physical existence of an absolute zero is inconsistent with the more accurate ideas of the nature of heat, which modern investigation has suggested.—*Dr Kane*.

Even in solids the effect of compression in reducing capacity for heat is very remarkable. By hammering a piece of soft iron, commencing the operation when the iron is at the common temperature of the atmosphere, its particles are more closely approximated, and the consequence is, a reduction of its capacity, and an evolution of heat; if the hammering be dexterously continued for some time, the iron becomes red hot. It is common among smiths to procure fire in this way. Great pressure

causes in the same way, and for the same reason, very sensible evolutions of heat. This is well seen in the process of coining, where the blank piece in sustaining the sudden and violent pressure of the coining-press becomes suddenly warm. Even a piece of Indian rubber, suddenly and forcibly stretched out, becomes warm in consequence of the greater approximation of its particles by the extension. This is readily perceived by applying it to the lip the moment it is extended, the lip being susceptible of very slight changes of temperature.

The development and absorption of heat, that is, the change of capacity of a body for heat, by change of density, seems to be easily derivable from Dr Black's *doctrine of latent heat.* According to this illustrious philosopher, heat exists in all bodies in two opposite states; in the one it is in chemical combination, exhibits none of its ordinary characters, and remaining as it were concealed, it evinces no signs of its presence; in the other it is free and uncombined, passes readily from one substance to another, affecting the senses and the thermometer in its passage, giving rise in fact to all the phenomena which are attributed to it as an active principle. According to this view it is intelligible how a substance by having its particles more nearly approximated may have its capacity for heat diminished, and *vice versâ*, even although no difference of thermometrical temperature be perceptible; and why evolution of heat is caused by compression, and absorption, by diminution of density. But in admitting the plausibility of this explanation, it is to be borne in mind that it is at present entirely hypothetical, and further that the language suggested by an hypothesis should not be unnecessarily associated with the phenomena upon which it is founded. Accordingly, the words *sensible* and *insensible*, are preferable to *free* and *combined* heat: the last not only imply the materiality of the agent, but likewise assume a perfect acquaintance with its relations to matter, and the present state of our knowledge does not warrant us in speaking determinately of either.

*Liquefaction.*—It has already been explained that when heat permeates the substance of a body, a change of density follows, and the effect is what we term expansion. But heat, besides effecting some nearly uniform change in the dimensions, exhibits in its course two singular transformations of the physical state of the body: the first, when the cohesive attraction is so far overcome that a solid breaks down into a liquid; and the second, when the liquid swells out into a vapour or gas. That the dissimilar forms of matter—the solid, the liquid, and the gaseous, are entirely dependent on its thermal state, is a fact of very general experience. In the lowest temperatures, bodies are solid: in higher temperatures they pass to liquids; and, in the highest of all, they become elastic gases.* The particular temperatures at which these changes take place in different bodies are exceedingly various, but they are always constant for the same body under equal circumstances. Confining ourselves in the mean time to the first of these transformations, we invariably find that

| | | | |
|---|---|---|---|
| Lead, melts at | 612° | Tallow, melts at | 92° |
| Bismuth, | 476 | Olive oil | 36 |
| Tin, | 442 | Ice, | 32 |
| Sulphur, | 232 | Milk, | 30 |
| Wax, | 142 | Wines, | 20 |
| Phosphorus, | 108 | Mercury, | —39 |

Conversely, if these bodies are in the liquid form, they become solid when cooled below the temperatures set opposite them. Those indeed which assume a crystalline structure when they solidify, present an apparent exception to this. Water, for instance, by precaution may be cooled considerably below the melting point of ice, but the instant any solid body is dropped into it, or that any agitation is communicated to it, congelation commences and the temperature rises to 32°. A solid body on the other hand cannot be heated the smallest fraction of a degree above its melting point without undergoing liquefaction. It is for this reason that the melting point of ice is chosen as a point in the graduation of thermometers, instead of the freezing point of water; the one takes place with rigorous constancy at 32°, the other may not take place till reduced to 5°. Moreover, all salts dissolved in water lower its freezing temperature, and with common culinary salt which appears to depress the point lower than any other saline body, the effect seems to be very closely proportional to the quantity of salt in the solution. Thus brine containing 1 part in 4 of water, freezes at 4°, and sea water which contains 1-30th of its weight of salt, freezes at 28°. When such a solution is brought to solidify, it is pure ice which first crystallizes, as is exemplified in the ice mountains of the polar seas, which are found to be almost completely fresh. Vegetable acids have the same effect of lowering the freezing point; and on the principle that fresh ice may be obtained from salt water, vinegar and lemon juice are concentrated by freezing the water which is mixed with them, the strong acids remaining liquid.

In experiments upon the liquefaction of bodies, one fact is particularly remarkable; it is this. During the change from the solid to the liquid form, a large amount of heat is absorbed and disappears, combining as it were with the substance of the solid to form the liquid, and becoming insensible to our feelings and our instruments. Any body which can be readily fused, might be chosen to illustrate this doctrine; for it applies to all cases of fusion; but the characteristics of ice and water, and the process of thawing are so familiar to us, as almost to preclude the selection of an example. If the bulb of a thermometer be imbedded in a piece of ice, the instrument will indicate the temperature of the ice: suppose it to be at the time 20°. If the mass of ice with the thermometer still immersed in it, be brought into a warm room the temperature of which is perhaps 60°, it there receives heat from the warm air and every object around it, and the thermometer gradually rises till it indicates a temperature of 32°. Until this, the ice remains hard and dry, but at 32° it begins to melt, and the melting process goes on till it is wholly converted into water. During the whole of the process the thermometer remains stationary at 32°, notwithstanding that heat must continue to enter as at first (between 20° and 32°), and which the instrument indicated. As soon as the liquefaction is complete, the mercury begins to ascend, and continues to do so between 32° and 60°, which being the temperature of the room, it can rise no higher. In the experiment it should also be observed that while the ice is melting, both the ice and the water are at the temperature of 32°, and that the water attains no higher temperature until the liquefaction is completed. It might further be observed, that whatever time was required to heat the mass of ice *one degree* between 20° and 32°, just 140 times as much is required to melt the mass, after its attaining the temperature of 32°.

The question which occurs is this: why did the thermometer remain stationary at 32° during the period of melting? We cannot suppose that the ice ceased at that point to receive heat from the warm air of the room and the objects in it; for then no reason could be assigned for the melting of the ice at all, and for the subsequent rise of the thermometer from 32° to 60°. The only other way of answering the question is, that heat continued throughout to enter the ice, but was expended in effecting a change in the physical condition of the body. It produced fluidity; but in producing this effect it became quiescent in the water, and so combined with it as to be incapable of affecting the thermometer. Heat continued to enter until as much was absorbed as was necessary to this altered condition, and there being no longer any ice to liquefy, the subsequent acquisition of heat became sensible or free, and then affected the thermometer.

However difficult it may be to conceive that heat enters the ice at the moment of melting without altering its temperature, it is certainly true, and can be proved by other experiments which admit of no doubt. If two similar tin flasks, one filled with ice at 32°, and the other with water at 32°, be placed under equal circumstances before a fire, or in an oven, the water will gain 140 degrees of heat, while the ice is merely being melted into water at 32°; and during the course of the experiment a correspondence will always exist between the quantity of ice melted and the augmentation of the temperature of the water. For instance, when the water has gained 14° of heat, a tenth part of the ice is melted, and so on for other quantities and tem-

* All substances are regarded as susceptible of these changes, although, on the one hand, the temperature required for the liquefaction and evaporation of some solids is extremely high, and on the other the temperature required for the reduction of many gases to the liquid state is unattainably low. Carbon, for instance, can hardly as yet be said to have been fused, and oxygen has not been liquefied. Organic substances being in general composed of carbon and gaseous elements, more or less volatile, are readily decomposed by the action of heat, though not liquefied. Some inorganic bodies are also decomposed before being melted. Marble, for instance, parts with its carbonic acid, and becomes lime when subjected to a white heat under the ordinary pressure of the atmosphere; but if placed under great pressure, it melts without parting with its acid. Similar experiments lead to similar results with many other bodies. In some instances, fusion is preceded by a softening of the substance, so as to admit of adhesion by welding. This is the case with porcelain, glass, iron, and platinum; and some other solids, as tallow and wax, pass through every degree of softness before they liquefy; such bodies are in general mixtures of two or more substances which crystallize imperfectly, and melt with different degrees of heat.

peratures. When ice, or better, snow is melted by means of hot water, the result is equally remarkable. As already understood, if a pound of water at 32°, be mixed with another pound at 172°, the temperature will be 102°, the arithmetical mean of the two temperatures. But substituting a pound of snow or pounded ice at 32°, for the water at 32°, what temperature ought the mixture to have? The thermometer shows it to be 32°. What then has become of the 140° of heat lost by the hot water? There is obviously no other way of explaining its disappearance than by admitting that it has been expended in converting the snow or ice into water: it produced this effect, but added nothing to the temperature.

From these experiments it then appears, that the difference between a pound of water at 32°, and a pound of ice or snow at 32°, is 140 degrees of heat,—the water not only containing as much heat as the ice, but such an additional quantity as would be adequate to heat another pound of water 140°.

It has already been remarked that a quantity of heat similarly disappears in the liquefaction of all bodies. If we select any body from the foregoing table, and imbed the bulb of a thermometer of sufficient range of scale in it, we shall find that the instrument will remain stationary at the melting point until the whole mass becomes fluid. Taking tin as an example, the thermometer will continue at 442°, till the whole mass is fused; and during the experiment, it may be observed, that the process of fusion takes 500 times as long as to raise the thermometer imbedded in the mass any one degree below the melting point, (supposing the source of heat to remain constant); thereby showing that 500° of heat disappear in liquefying the tin, or as much as would be sufficient to raise the temperature of liquid tin 500° higher.

It may be asked if the heat which disappears in this manner is destroyed? Can it be extricated and recovered again? These questions are most forcibly answered by reversing our experiments. If a vessel of water at a temperature of 52°, be exposed freely to a temperature below the freezing point, it will rapidly cool until it arrives at 32°, but then the lowering of the temperature ceases; it begins to freeze, but until the whole is converted into ice no loss of heat is indicated by the thermometer. It must however be giving out heat precisely as it did in cooling from 52° to 32°, and this heat is that which gave it the fluidity of water. This is beautifully evinced by the fact that the process of freezing takes just 140 times as long to complete as the water took to give out 1° of heat when its temperature was above 32°. For instance, suppose the water takes ten minutes to cool from 52° to 32°, that is 20°, it will require an hour and ten minutes to be completely frozen; and during that time will give out $20° \times 7 = 140°$ of heat, This experiment, performed upon other fused bodies, leads uniformly to the same conclusion, that none of the heat of fluidity is lost, but is all again extricated or given out during the passing of the body into the solid state.

There is another form of the experiment which shows more forcibly that this evolution of heat actually does take place during congelation. If pure recently boiled water be carefully cooled down to 22° without freezing, it is then 10° degrees below the freezing point; but the least motion causes a portion of it instantly to freeze, and the temperature of the whole rises to 32°. Here 10° of heat are acquired in an instant, for which there is no other way of accounting than that the heat is derived from that part of the water which suddenly froze. Similarly, when a supersaturated solution of sulphate of soda (glauber salt), formed by dissolving three pounds of the salt in two pounds of water, is set aside to cool with a few drops of oil on its surface, it remains fluid, although containing a much greater quantity of salt in solution than the water could dissolve at the temperature to which it falls. When the temperature is as far depressed as the state of the atmosphere will allow, slight agitation, or the introduction of a small crystal of the salt, will commence the crystallization, which will proceed with great rapidity, and the temperature will rise 30 or 40 degrees.

These and similar facts led Dr Black to the hypothesis of latent heat, already referred to. Before the views of that philosopher were made known, fluidity was universally attributed to a very small addition of heat to that which the body contained when its temperature had reached the melting point. It was in fact believed, that a solid body, when it changed into a liquid, received no greater addition of heat than was indicated and measured by the rise of the mercury in the thermometer. Neither was the converse of this questioned. The liquid was believed to pass into the solid state without further loss of heat than the thermometer indicated. Uniform experience is at variance with these views. Both liquefaction and solidification are processes which require time; but were there no ingress or egress of heat other than is indicated by the thermometer, both would take place instantly when the temperature of the body reached the particular point at which the transition takes place. Masses of ice and snow, instead of melting with extreme slowness—often requiring, even in this country, many weeks of warm weather to melt them into water—would dissolve into torrents and inundations on the slightest rise of temperature. On the other hand, the cold of a single night might be sufficient to freeze an ocean,—a state of things which would render the earth, except in its tropical regions, scarcely habitable.

We do not know the latent heat of many liquid bodies. Those in the following table, with the exception of water, were determined by Dr Irvine. The numbers are given in two columns—the first showing the interval through which the body itself would be heated by the heat it absorbs in melting, and the second, the interval through which that heat would elevate the temperature of an equal weight of water:—

| Latent heat of | Measured by itself. | Measured by water. |
|---|---|---|
| Water, (Dr Black) | 140 degrees. | 140 degrees. |
| Sulphur, . . . | 144 ... | 27·14 ... |
| Lead, . . | 162 ... | 5·6 ... |
| Ditto, (Rudberg) . | 370 ... | 10·93 ... |
| Zinc, . . | 493 ... | 48·3 ... |
| Tin, . . . . | 500 ... | 33 ... |
| Bismuth, . . | 550 ... | 23·25 ... |

The large quantity of heat, which becomes latent during liquefaction, affords a ready explanation of many artificial processes for producing cold. All of them are conducted on the principle of liquefying solids without the aid of heat: and if liquefaction suddenly takes place under these circumstances, as the necessary heat of fluidity must be derived from the surrounding bodies, and from the heat which previously existed within the body itself in a sensible state, it is obvious that the temperature must fall in proportion to the amount of heat absorbed and the rapidity of the absorption. Nitre, for instance, dissolves rapidly in water, and cools it about 18 degrees in consequence. A mixture of five parts of sal ammoniac, and five of nitre, both finely pounded, dissolved in nine parts of water, reduces its temperature 40°. The common freezing mixture of common salt and snow, or pounded ice, is a better known and still more remarkable instance of the disappearance of heat by liquefaction. If these substances be mixed together in a thin vessel, in about the relation of 2 of snow to 1 of salt, the whole will rapidly become liquid, and a thermometer plunged into the mixture will stand at 0°. It was in this way that Fahrenheit is supposed to have determined the zero of his scale. It is also by this means that ices are commonly procured for the tables of the rich in summer. A quantity of ice from the ice-house is roughly pounded and mixed with salt: the liquid to be frozen is then poured into a thin metallic pan, and placed in the cold brine, which speedily withdraws its heat.

The liquefaction of snow by means of crystallized chloride of calcium occasions a still greater degree of cold. This salt may be made by dissolving marble in hydrochloric acid (spirit of salt), and concentrating the solution by evaporation at a temperature not exceeding 300°. As it becomes dry at this temperature, it should be stirred so as to become a fine crystalline powder. From its extreme deliquescence it must be preserved in well stoppered vessels. When 3 parts of this salt are mixed with 2 of dry snow, the temperature is reduced from 32° to —50°, that is 82°; and if the ingredients are previously cooled down to 0°, a mixture of 2 of the salt and 1 of snow produces a cold of —66°. The mercury in a thermometer may be readily frozen by immersion in one of these mixtures.

The methods of producing intense cold have been very fully investigated by Mr Walker, from whose paper in the Philosophical Transactions we select those of the following table, which also contains those already mentioned:—

| Mixtures. | Parts. | Thermometer sinks. |
|---|---|---|
| Muriate of ammonia,<br>Nitrate of potash,<br>Water, . . . | 5<br>5<br>16 | From + 50° to + 10°. |
| Nitrate of ammonia,<br>Water, . . . | 1<br>1 | From + 50° to + 4°. |
| Nitrate of ammonia,<br>Carbonate of soda,<br>Water, . . . | 1<br>1<br>1 | From + 50° to — 7°. |
| Sulphate of soda, .<br>Dilute nitric acid, | 3<br>2 | From + 50° to — 3°. |
| Snow or pounded ice,<br>Common salt, . | 2<br>1 | From any to — 5° |
| Snow or pounded ice,<br>Dilute nitric acid, . | 7<br>4 | From + 32° to — 30°. |
| Snow or pounded ice,<br>Chloride of calcium, | 2<br>3 | From + 32° to — 50°. |
| Snow or pounded ice,<br>Potash, . . | 3<br>4 | From + 32° to — 51°. |
| Snow, . . . .<br>Chloride of calcium, | 1<br>3 | From — 40° to — 73°. |
| Snow, . . . .<br>Dilute sulphuric acid, | 8<br>10 | From — 66° to — 91°. |

There are means of producing more intense degrees of cold than those mentioned in the table; but the last temperature noted, namely, — 91°, is such as to convert all liquids, with the exception of alcohol, into the solid form. Common spirits freeze during severe colds; but there is no positive evidence that absolute alcohol (sp. gr. 0·798) has yet been congealed. Mr Hutton indeed announced that he had congealed it by reducing its temperature to —110°; but Leslie subjected it to a cold of —120° without observing any congelation. Muncke, too, calculated its freezing point at —140°; but Mr Kemp cooled it down to —163°, by means of solid carbonic acid, and yet it retained all its fluidity.

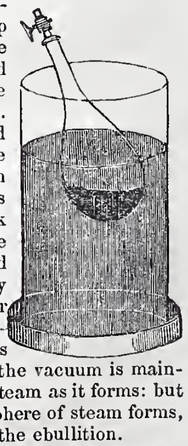
*Vaporization.*—When bodies are subjected for a length of time to a higher temperature than is necessary to liquefy them, they are in general converted into vapour, of which steam is a familiar instance. When a substance exists in this form, it possesses in all respects the mechanical properties of air, but is subject to be condensed into a liquid or solid by reduction of its temperature within known limits. Gases, on the contrary, retain their elastic state at all common temperatures, and, with one or two exceptions, cannot be made to change their form except under great pressure; and some of them have hitherto resisted every effort to compress them into liquids.

Various bodies pass into the state of vapour with very different degrees of facility. Although it is the received opinion that a sufficiently intense heat will convert every liquid and solid into the aeriform state, there are still some which resist the most intense heat which we can command. Others again pass into vapour at exceedingly low temperatures. There are some solids also, as camphor and arsenic, which are converted at once from the solid to the vaporous condition; but in general, liquefaction precedes vaporization. Substances again, which exist at ordinary temperatures in the liquid form, are in general more easily vaporized than solids; but to this, too, there are exceptions. Experience further informs us that the passage of a substance to the vaporous condition may occur rapidly and with violence, as when a liquid boils; or it may take place slowly and silently, as when a liquid spontaneously evaporates. These modes of generating vapours have indeed led to the study of the subject under the two heads of *ebullition* and *evaporation*, and from their respective importance, they require to be separately and specially examined.

When a liquid is heated in an open vessel to some fixed point of temperature, called its *boiling point*, a rapid formation of bubbles of vapour takes place around the lower part of the vessel; and these rising rapidly through the liquid, and increasing in size as they rise, disappear at the surface. It is to this violent commotion of the liquid consequent on the rapid generation of vapour, that we give the name of *ebullition*, and the point of temperature at which it commences is the *boiling point* of the liquid. This point varies with the nature of the liquid. Thus ether boils at 97°, spirit of wine at 172°, pure water at 212°, while oil of turpentine must be raised to 315°, sulphuric acid to 630°, and mercury to 660°, before they exhibit signs of ebullition. The boiling point of the same liquid is constant so long as the necessary conditions are preserved; but it is liable to be altered in a slight degree by the nature of the vessel in which it is contained, in a greater degree by the presence of foreign matter, and most materially by the pressure to which it is subjected. Thus, water which boils at 212° in a metallic vessel will require to have its temperature raised to 214° before it begins to boil in a glass vessel. The introduction of a little gum-arabic raises its boiling point some degrees higher. But the degree of pressure to which the liquid is at the time subject, is the most important circumstance for consideration. It is explained in pneumatics that although the air is an exceedingly light substance—being 815 times lighter than water—yet by reason of its great quantity and height, it comes to press upon the earth with a force of nearly 15 pounds on every square inch of surface. This is called the *atmospheric pressure;* and all bodies upon the earth are constantly subject to it. Its influence upon liquids is to raise their boiling points about 140° higher than they would otherwise be. This is proved by making them boil *in vacuo.* Under these circumstances water enters into ebullition at 72°, alcohol at 32°, and ether at —43°. This proves further that a liquid is not necessarily hot because it boils. The heat of the hand is sufficient to make water boil in a vacuum, as is exemplified by the little instrument called the pulse-glass; alcohol boils at the freezing point of water, and ether, under the same circumstances, will enter into ebullition at a temperature below that which would render mercury solid.

If in making experiments upon the boiling point of a liquid under reduced atmospheric pressure, by placing the vessel containing it under the receiver of an air-pump, and exhausting the air, we stop working the pump at the moment that it is in violent ebullition, the vapour accumulates, and exercises on the surface an amount of pressure corresponding to its elasticity at the existing temperature; and this by raising the boiling point stops the ebullition.

This is well shown in a very simple and paradoxical manner as follows: Fit a stop-cock securely to the mouth of a Florence flask, containing a little water, and heat it over a spirit lamp, till steam issues freely through the open stop-cock, then suddenly withdraw the lamp and shut the stop-cock, the water of course ceases to boil; but if the flask be plunged into a vessel of cool water, as shown in the figure, ebullition immediately recommences. If it be taken from the cold water and held before the fire, or be placed in hot water, the boiling ceases, although it may again begin when replaced in the cold water. In this experiment the air is driven out of the flask by the steam generated in boiling over the lamp; and the atmosphere of steam included when the stop-cock is shut, is condensed by immersion in the cold water, and the water in consequence begins to boil when the pressure upon its surface is removed, although its temperature is at the same time lowered: the vacuum is maintained by the constant condensation of the steam as it forms: but on removal to a warm medium, a new atmosphere of steam forms, presses upon the enclosed liquid, and stops the ebullition.



As the pressure of the atmosphere is not always the same at the same place, as is shown by the variations of the barometer, it may be anticipated that the boiling points of liquids are subject to fluctuation. Thus, it is only when the mercury stands in the barometer at $29\frac{8}{10}$ inches that water boils at 212°; when the mercury stands at a greater or less height, there is a corresponding elevation or depression of the boiling point in the pro-

portion of $1\frac{3}{4}^{\circ}$ to the inch of mercury. This explains why water boils at a lower temperature on the tops of mountains than at their bases; the pressure of the atmosphere always becoming less as we ascend. On the top of Mount Blanc, for instance, water was observed by Saussure to boil at 184°. In deep pits, on the contrary, the boiling point is elevated because the atmospheric pressure is there augmented. It is upon this principle that the heights of mountains are determined, by observing the temperature at which water boils upon their summits. The calculation is very simple for ordinary heights. An ascent of 530 feet causes a depression of the boiling point 1°; so that according to Saussure's observation, the height of Mount Blanc above the sea is 14,840 feet.

The facility with which liquids boil under reduced atmospheric pressure is frequently taken advantage of in the arts, in concentrating liquors which would be injured by exposure to the heat necessary to boil them, under the common atmospheric pressure. Thus, in sugar refining, the syrup is boiled at 150°, and this low temperature is obtained by using a pan with an air-tight lid, and pumping off the air and steam from the surface of the liquid by means of a steam-engine. This is the most essential part of Howard's patent, by which nearly the whole of the loaf-sugar consumed in this country has been manufactured for several years. In pharmaceutical laboratories, the same method is had recourse to on a smaller scale, to concentrate infusions and expressed juices which a high heat would tend to impair. Reversing this state of things, and exposing liquids to artificial pressure, we may elevate their boiling points almost as high as we please. For instance, in Papin's Digester, which is a strong kettle, having a lid very nicely fitted to it, and secured by screws, the temperature of the water may be raised sufficiently high to melt a piece of lead immersed in it, without a bubble forming. It may indeed be possible to render the water red-hot; but the tendency to expand into steam becomes ultimately so great as to burst any known material of moderate thickness. Of this the well-known experiment by the Marquis of Worcester, in exploding a cannon by shutting up water in it, and surrounding it by fire, is a proof. The little toy called a *candle-cracker*, which is a small bubble of glass, hermetically sealed and containing a drop of water, affords no bad illustration of the force with which a liquid tends to pass into vapour when heated above its boiling point: when placed in the flame of a lighted candle, it explodes in a few seconds with great violence.

We have hitherto spoken of the boiling point of a liquid as that point of temperature, at which it begins to throw off bubbles of vapour; but it may be necessary to explain, that this, like the melting point of a solid, remains constant during the whole process of ebullition. When cold water is placed over a steady fire, in an open metallic vessel, the thermometrical temperature gradually rises until it begins to boil; but there it remains perfectly stationary, till the last drop of water has passed off in vapour. This is true, however violently it may be made to boil,—a fact which is of importance in domestic economy, as showing that soups and the like, made to boil in the most gentle way, by the application of a moderate heat, are just as hot as when the boiling is urged to violence by the strongest fire. If we remark the time necessary to heat the water to its boiling point, and that required to boil it to actual dryness, we shall find the following relation. Supposing that the original temperature of the water was 52°, and that it began to boil in 13 minutes; by a continuance of the same heat for other 50 minutes, it is entirely boiled off. This is the result of experiment, not of calculation; but observe the calculation which is founded upon it. In attaining the boiling temperature, the water in each minute would receive $\frac{212^{\circ}-52^{\circ}}{13} = 20^{\circ}$ of heat; but the fire remaining steady, every successive minute of the 50 which is required to boil off the water, supplies also 20° to it; that is in all $20^{\circ} \times 50 = 1000^{\circ}$, or as much heat is thrown into the water after it begins to boil as should elevate its temperature 1000°, yet the thermometer does not rise above 212°, either in the water or in the steam which rises from it.

The question occurs—what becomes of this large amount of heat? Has it, as in the case of liquefaction, become latent in, and passed off with, the steam? That this question ought to be answered in the affirmative, is readily proved by condensing the steam which is given off from boiling water; and it is found that a pound of steam at a temperature of 212°, is just sufficient to elevate the temperature of 10 lbs. of cold water 100°, or to melt $7\frac{1}{7}$ lbs. of ice at 32°. An apparatus has been invented to illustrate this; but there is in fact no better mode of exemplifying the whole phenomena than by reference to the common still and worm-tub. Here the boiling point differs from that of pure water, according to the nature of the fluid operated upon; but it may be uniformly remarked during the whole process, when ebullition is once begun in the still, the temperature remains stationary, notwithstanding the action of a strong fire; all the heat supplied is absorbed by the vapour. On the contrary, the water in the worm-tub becomes hotter and hotter during the passage of the vapour into the liquid state, and were it not that the cold water is constantly being renewed, it would rapidly be made to boil, and the process could not be carried on.

Upon the same principle, it is common in breweries and manufactories where large quantities of hot water are required, to warm it by conveying steam either directly into the water or in pipes passing through the vessels. The same agency is also applied, as every one knows, to the warming of buildings; the steam being made to circulate in pipes passing from a boiler through all the apartments, gradually condenses and gives out its latent heat to the pipes which diffuse it by radiation. In several chemical operations also, in which exposure to the direct action of a fire might be injurious, steam is employed as the source of heat: and it is admirably adapted for many of the processes of cooking, though the want of convenient apparatus has as yet prevented its virtues, in this respect, from being fully recognised.

In the great amount of heat which becomes latent in steam, we perceive the reason why water projected upon a raging fire so powerfully represses it. It is owing also to the same cause that vaporization is a progressive process; and it may be observed that had the constitution of liquids been such, that upon reaching their boiling points, they would at once have passed into the aeriform state, the boiling of a tea-kettle, as Mr Daniel remarks, would have been a service of imminent danger; the whole volume of water would at once have flashed into steam with explosive violence.

The latent heat of the vapour of several other bodies besides water has been determined. The method employed is simply, to distil a known quantity of the liquid, and to condense its vapour in a known quantity of cold water, and to note accurately the elevation of temperature which it causes. In this way, it is found that the latent heat of the equal weights of the following bodies is sufficient in condensing, to raise the temperature of an equal weight of water as many degrees as stand against them:—

| | | | |
|---|---|---|---|
| Water, . . . . . | 1000° | Oil of turpentine, . . | 138° |
| Alcohol, (sp. gr. 793) | 376° | Nitric acid, (sp. gr. 1·494) | 335° |
| Ether, (sp. gr. 715) . | 163° | Naphtha, . . . . | 74° |

All bodies when they pass into the vaporous condition have their volumes greatly increased, and this expansion is more remarkable in water than in any other liquid. The amount of increase, supposing the liquids to be boiled off under the ordinary pressure of the atmosphere, and the vapours to be subject to no other pressure, is exemplified in the instances contained in the following table:—

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | measure of | water . . | becomes | 1696 | measures of vapour | at 212° |
| 1 | — | alcohol . . | — | 488 | — | — 172° |
| 1 | — | ether . . | — | 240 | — | — 97° |
| 1 | — | oil of turpentine | — | 221 | — | — 315° |
| 1 | — | mercury . . | — | 3395 | — | — 660° |

It has been imagined that there must necessarily exist a physical connexion between the latent heat of vapours and their increase of volume, consequent on their change from the liquid to the aeriform state, and this appears to be true so far as our knowledge of the latent heat of bodies goes. Thus, those bodies as ether, and oil of turpentine, which render the least quantity of heat latent during their change, expand the least. Assuming therefore that the principle is true generally, it follows that the same, and just the same amount of vapour will be produced from all liquids with the same expenditure of heat. It also follows, that the substitution of alcohol, ether, and turpentine, as sources of vapour in the steam-engine, as has been sometimes proposed on account of their less latent and sensible heat, would be attended with no advantage in point of economy, even if they could be procured as cheaply as water.

# MATHEMATICS.

## CHAPTER IV. (*Continued.*)

### DIVISION OF WHOLE NUMBERS.

12. When the divisor is not greater than 12, a sufficient knowledge of the multiplication table enables us to abridge the foregoing process. To show how this is accomplished, suppose that it is required to divide 38024 by 7. The operation is shown on the margin at full length.

But it is easy to recollect, without being at the trouble to write it down, that 38 divided by 7, gives a remainder 3; this 3, placed before the next figure of the dividend *mentally*, makes 30, which divided by 7, gives a remainder 2; this 2 again placed before the 2 of the dividend makes 22, which divided by 7, gives a remainder 1; this placed before 4, the last figure of the dividend, makes 14, which divided by 7, gives a remainder 0.

Common Process.

7) 38024 (5432<br>
35<br>
—<br>
30<br>
28<br>
—<br>
22<br>
21<br>
—<br>
14<br>
14<br>
—<br>
0

13. This method is likewise applicable when the divisor can be resolved into two or more factors not exceeding 12. For as in multiplication, we may multiply successively by the factors of the multiplier (Chap. iii. art 7), so in division we may reverse the process, and divide a dividend successively, by the factors of a divisor, (the dividend being regarded as a product obtained by multiplying the quotient by all the parts of the divisor).

Abridged Process.

7) 38024<br>
5432

Thus since $7964 \times 48 = 7964 \times 6 \times 8 = 47784 \times 8 = 382272$
Therefore $382272 \div 48 = 382272 \div (6 \times 8) = 47784 \div 6 = 7964$.

The method of applying this principle is shown in the following examples, where it will be observed, that the order in which the factors are taken, is unimportant.

| Divide 709695 by $63 = 7 \times 9$ | | Divide 1573056 by $44 = 11 \times 4$ | |
|---|---|---|---|
| Processes. | | Processes. | |
| 9) 709695 | 7) 709695 | 4) 1573056 | 11) 1573056 |
| 7) 78855 | 9) 101385 | 11) 393264 | 4) 143005 1 |
| 11265 | 11265 | 35751 3 | 35751 1 |

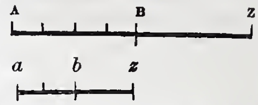
In the last question, we perceive, there is a difficulty, in the case of the remainder: by the first process we obtain 3 over at the final division, and by the second we get 1 at each division. But if we try the question by the common method, we find that the true remainder is 12: we must therefore determine some method of finding this number from the partial remainders obtained. Now we observe that

$$4 \times 3 = 12 \text{ and } 1 \times 11 + 1 = 12$$

that is, the *last* partial remainder multiplied into the *first* partial divisor gives the true remainder when there is no previous partial remainder; but when there is a preceding remainder it must be added to the product. This rule must, in the mean time, be taken empirically, but the reason of it will be made perfectly obvious, when treating of the addition of fractions.

14. That the quotient is not altered by dividing or multiplying both dividend and divisor by the same number is clear; for since the object of division is to find how often one number is contained in another, it follows, 1st, That the greater or less the dividend, the greater or less the number of times it will contain the divisor, and consequently the greater or less the quotient; 2d, That the greater or less the divisor, the less or greater the number of times it will be contained in the dividend, and consequently the less or greater the quotient. Therefore *both* the divisor and dividend may be multiplied or divided by any number whatever, without affecting the quotient; because, as much as the quotient is increased by multiplying the dividend, just so much will it be diminished by multiplying the divisor, and as much as the quotient is diminished by dividing the dividend just so much will it be increased by dividing the divisor.

This may be rendered obvious to the eye. Let A B be a rod of 4 feet long, and $a\,b$ a rod 2 feet long; the length $a\,b$ is contained in the length A B twice. Double the length of both rods, that is, let A B become A Z and $a\,b$ become $a\,z$; the length $a\,z$ is contained in the length A Z just twice as before. In other words, the quotient contains the same, when both divisor and dividend are multiplied by the same number.




Conversely, let A Z be a rod 8 feet long, and $a\,z$ a rod 4 feet long, the length A Z contains the length $a\,z$ twice. Take A B half of A Z; and $a\,b$ half of $a\,z$; and the length A B continues the length $a\,b$ twice. In other words the quotient is not altered when both divisor and dividend are divided by the same number.

15. As, $16 \times 10 = 160$; therefore $160 \div 10 = 16$
$16 \times 100 = 1600$; therefore $1600 \div 100 = 16$

the division by 1 followed by ciphers is therefore effected by cutting off as many places on the right side of the dividend as there are ciphers in the divisor. In the cases above, these places are occupied by ciphers, but the principle is equally true although these places are occupied by significant figures, the figures cut off forming a remainder. Thus supposing it is required to divide 78546 by 100. The dividend 78546 is 785 hundreds and 46; that is $78500 + 46$ but 78500 contains 100, 785 times, and 46 not at all; the quotient is therefore 785, and the remainder 46. The operation according to the ordinary method is shown at the side.

100) 78546 (785<br>
700<br>
——<br>
854<br>
800<br>
——<br>
546<br>
500<br>
——<br>
46

This principle may in effect be extended to cases where the divisor is any figure or figures followed by ciphers. Thus suppose we are required to divide 854326 by 6000. We know that $6000 = 6 \times 1000$ and $854326 = 854000 + 326$; now 854000 contains 1000, 854 times, and 326 not at all; 854 is therefore the quotient by 1000, and the remainder 326. This is therefore resolved into the division of 854 by 6, which gives for a quotient 142 and remainder 2. This remainder placed on the left of the remainder arising from the division by 1000, gives the complete remainder 2326.

6000) 854326 (142<br>
6000<br>
———<br>
25432<br>
24000<br>
———<br>
14326<br>
12000<br>
———<br>
2326

16. The rule is this: cut off as many places of figures from the right of the dividend as there are ciphers on the right of the divisor; cut off all the ciphers on the right of the divisor, and divide the abridged dividend by the abridged divisor in the usual way. The following examples showing both methods will make this plain:—

| Common Process. | Abridged Process. |
|---|---|
| 3996000) 89764200000 (22463 | 3996) 89764200 (22463 |
| 7992000 | 7992 |
| 9844200 | 9844 |
| 7992000 | 7992 |
| 18522000 | 18522 |
| 15984000 | 15984 |
| 25380000 | 25380 |
| 23976000 | 23976 |
| 14040000 | 14040 |
| 11988000 | 11988 |
| 2052000 | 2052000 |

| Common Process. | Abridged Process. |
|---|---|
| 30400000) 16014387161 (526 | 304) 160143 (526 |
| 152000000 | 1520 |
| 81438716 | 814 |
| 60800000 | 608 |
| 206387161 | 2063 |
| 182400000 | 1824 |
| 23987161 | 23987161 |

To divide by 5, multiply by 2, and strike off the last figure, half of which is the remainder, and what precedes is the quotient.

For $2150 \div 5 = (2150 \times 2) \div (5 \times 2) = 4300 \div 10 = 430$.

Reciprocally, the easiest way of multiplying by 5, is to annex a cipher and to divide by 2.

To divide by 25, multiply by 4, and strike off the last two figures, which leaves the quotient; and a fourth part of the figures struck off, considered as one number, is the remainder.

For $1725 \div 25 = (1725 \times 4) \div (25 \times 4) = 6900 \div 100 = 69$.

Reciprocally, to multiply by 25, annex two ciphers, and divide by 4.

As multiplication and division are exactly inverse operations, it is unnecessary to prescribe any other mode of forming exercises in this rule; for the division of one number by another being effected, the correctness or incorrectness of the result is at once proved by multiplying the quotient by the divisor, and adding the remainder if any; this final result ought to be the dividend. As this however is like working without an object, the student may prove for himself that the following formulæ are true, whatever numbers we put for A and B, (provided always that A be made greater than B.)

$$\frac{A \times A - B \times B}{A - B} = A + B \quad \frac{A \times A + 2 \times A \times B + B \times B}{A + B} = A + B$$

Thus supposing $A = 169$ and $B = 37$; the formulæ assert that

$$\frac{169 \times 169 - 37 \times 37}{169 - 37} = 169 + 37 = 206$$

$$\frac{169 \times 169 + 2 \times 169 \times 37 + 37 \times 37}{169 + 37} = 169 + 37 = 206.$$

*Question.* Suppose there are one thousand millions, six thousand five hundred and sixty human beings in the world, and that the average of life is 36 years of 365 days; how many die every day? *Ans.* 76104.

## ANATOMY AND PHYSIOLOGY.

### CHAPTER V.

THE MUSCLES AND MUSCULAR ACTION.—*Continued.*

Every motion of the body is performed by its muscles,—they move us from one place to another; and without them we could not enjoy the pleasures of locomotion. Birds fly, fishes swim, insects run, and reptiles creep by muscular power. I lay down my arm by a layer of muscles placed below it for this purpose. I raise it by another layer placed above it. Into whatever position I put my body, turn, and twist it, the movements are not only muscular, but more mechanically just, than the motions of the nicest adjusted machinery of a patent-chronometer, or the correctly arranged apparatus of the best high-pressure engine. If I speak, sing, or whisper, the muscles of my windpipe, and tongue, minutely contract in almost an infinity of movements without my consciousness, and produce the sounds required, according to the exactest laws of oral expression, and musical harmony. The tongue and its motions are muscular. The eyeballs are mechanically moved and adapted to the laws of optics by their muscles. The collection and communication of the vibrations of air by the external ear, and the motions of the little bones of the internal ear, by which sounds are conveyed to the auditory nerve and brain, are the result of the most beautifully correct and harmonious muscular action. The peristaltic motion of the bowels is muscular. Eating, swallowing, ejecting, and dejecting, are simply the result of muscular power. Without the muscles, man would be a mere automaton, having the external human form without the faculty of locomotion, and lie inactive in whatever position he was placed, like a fallen statue, exposed to the winter storm and the summer sun, without the means of defence, and perish in utter helplessness by the inclemency of the seasons, of nakedness, hunger, and thirst. If man were not endowed with muscular power, he would naturally fall forward; and, according to the laws of gravity, he could not stand erect. It is muscular power that not only preserves his upright position, but makes him move slowly, rapidly, gracefully, and slovenly as he feels inclined. The mechanism and adaptation of the muscles is based, like other mechanical action, on lever power—a convincing proof that our Almighty Creator is not only infinitely wise and provident, but has made and adapted them according to the most perfect mechanical laws. Muscles are composed of fibrin, albumen, gelatine, extractive phosphate of soda, phosphate of ammonia, phosphate of lime, and carbonate of lime. Their atomical composition, by bulk, is one atom of oxygen, and three atoms of hydrogen.

To prevent any misapprehension among readers, I may simply mention, that by the muscles—I mean those parts of the body commonly known by the name of lean flesh. In my last essay I described the mechanism and functions of the muscles of the head, and also the cartilages of the windpipe. In my present essay, I will begin where I terminated in my last. The subject cannot fail to be interesting to mechanics and students, and indeed to every person who wishes to understand the structure and functions of his own body. The individual who is ignorant of this knowledge, notwithstanding all his other acquirements, is destitute of the first and best elements of domestic, social, and philosophical education. I feel sorry that I am obliged to give so many of the semi-barbarous old anatomical names of the muscles in describing their mechanism and action, for they are not known by any other nomenclature. The origin of these obsolete names is generally derived from the Greek; and if properly understood, they are intended to express their appearances, shape, situation, uses, and action. But why they should always remain in this Greekish jargon, is an anomaly I cannot explain, otherwise than for the sake of making them harmonize with the enigmatical Latin prescriptions, affected pomposity, assumed gravity, and mysterious taciturnity of the dignified medical profession, that in many instances (so unchangeable are its manners), for the last two hundred years, has not made one decided attempt at a rational reform. In these untoward circumstances, it might be deemed presumptuous, were I to attempt to change, in this Journal, the anatomical nomenclature which has been so gravely sanctioned by so many learned anatomists and great public teachers in ancient and modern times. But notwithstanding all this conservatism, there have, nevertheless, been many important suggestions and practical hints devised for its reformation, by some of the most celebrated private anatomical lecturers of the age. Dr. Robert Hunter, the eminent professor of surgery in the Andersonian University, Glasgow, proposed, in a medical periodical, as an improvement, to describe the muscles simply by *enumeration*, and gave us some examples of the facility and utility of his plan; but as it was not generally appreciated by our celebrated public anatomists, who claim the privilege of being the legitimate leaders of professional fashions, it fell to the ground in embryo, like many other great abortions of ingenious minds.

As the technicalities of anatomy make learned treatises on this subject sealed books to the masses—for the use of mankind they ought to be simplified.

There are three muscles on the throat which pull it downward; 1st, The sterno-hyoideus, a broad flat riband-like muscle, passing from the sternum (or breast bone), to the os hyoides (or bone of the tongue). It pulls the throat directly downward. 2d, The sterno-thyroideus, a flat, smooth, riband-like muscle, thicker and fleshier than the former, and very uniform in bulk, passes

from the sternum to the thyroid cartilage, and pulls the throat downward. 3d, The omo-hyoideus, a long, slender muscle, reaches from the shoulder to the os-hyoides. If this muscle acts singly, it pulls the throat to one side; if both act, one on each side, their power is equally balanced, and they assist the two former in pulling the throat directly downward, and at the same time it presses the windpipe a little downward and backward. These three muscles are almost continually in action, and are only completely relaxed when we are eating,—their relaxation permits the throat to be drawn upward, and the mouth thrust a little backward, which always happens during deglutition, which cannot be performed otherwise.

There are four muscles on the neck that pull the throat upward. 1st, The mylo-hyoideus, a flat broad muscle (arising from the whole semicircle of the lower jaw), divided by a tendinous white substance down its middle, in a line with the chin, and inserted at the base of the os-hyoides at the root of the tongue. Some anatomists divide this muscle into two, and call them distinct muscles. 2d, Genio-hyoideus, a neat pair of muscles, beautiful and radiated, arising from a small tubercle behind the chin, implanted into the basis of the os-hyoides. The sub-maxillary gland lies between this muscle and the omo-hyoideus, and in the middle, the duct of the gland pierces the membrane of the mouth, to open beneath the root of the tongue. The mylo-hyoideus, and genio-hyoideus, move the bone of the tongue forward and upward, when the lower jaw is fixed; but when the os-hyoides is fixed by the muscles that come from the sternum or breast bone, they pull the jaw downward. 3d, The stylo-hyoideus is one of three beautiful slender muscles, arising from about the middle of the styloid process, and is fixed into the side of the os-hyoides. Its fibres split above its insertion, and form a neat small loop for the passage of the tendon of the digastric muscle. The one of the other two-styloid muscles is inserted into the pharynx, and the other into the tongue; their common action is to draw back the tongue, and pull up the throat. 4th, The digastricus, is a double-bellied muscle; the one belly arises from the root of the mastoid process, and, proceeding obliquely forward and downward, passes by the side of the os-hyoides, slips through the loop of the stylo-hyoideus, and is fixed by a tendinous bridle to the side of the os-hyoides; and then, turning upward towards the chin, ends in a second fleshy belly, which is inserted into the lower jaw on the inside of its circle. This muscle, along with the stylo-hyoideus, pulls the throat upward and backward.

There are seven muscles on the throat that move the parts and the cartilages of the windpipe upon each other.

1st, The hyo-thyroideus goes from the thyroid cartilage to the os-hyoides, and compresses and shortens the windpipe. 2d, The crico-thyroideus, passes from the upper edge of the cricoid, to the lower margin of the thyroid cartilage, and also compresses and shortens the windpipe. 3d, Musculus arytenoideus transversus, arises from almost the whole length of one of the arytenoid cartilages, and is inserted to the same extent into the other. It contracts the glottis by drawing the cartilages towards each other. 4th, Arytenoideus obliquus, arises from the root of one arytenoid cartilage, goes obliquely into the other, draws them together, and closes the rima glottidis. 5th, Crico-arytenoideus-posticus, a small pyramidal muscle arising from the back part of the cricoid, is inserted into the posterior portion of the thyroid cartilage. It pulls the arytenoid cartilages directly backward, lengthens the slit of the glottis, and by closing it neatly, produces some of the most delicate modulations of the voice. 6th, Crico arytenoideus lateralis, comes from the sides of the cricoid, and is implanted into the arytenoid cartilage. It pulls them asunder, and slackens the lips of the rima glottidis, or opening of the windpipe. 7th, The thyreo-arytenoideus, arises from the posterior surface of the wing of the thyroid, and is implanted into the anterior part of the arytenoid cartilage. It pulls them forward and sideways, slackens the ligaments, and widens the glottis.

There is yet another muscle, the thyreo-epiglottideus, which has been divided by Albinus into major and minor; but it is frequently wanting. There are also a set of fibres, sometimes seen running from the arytenoid cartilage to the epiglottis, called the aryteno-epiglottideus, but in many subjects they are also not present. When the masticated morsel in the mouth, after being chewed, is prepared to be swallowed, the velum palati (or curtain of the palate), depending at the posterior part of the mouth, is drawn upward, and the opening of the throat is expanded. But whenever the morsel has passed down into the œsophagus or gullet, the curtain of the palate again falls down; for when the arch of the throat is contracted, and the gullet is compressed by its own muscles, the food is then forced downward into the stomach, more by muscular action than its own gravity. Indeed, the muscles of the throat can perform this function very easily against the laws of gravity altogether; for sometimes we see showmen and mountebanks with facility swallowing food and liquids, while standing erect on their heads, with their feet uppermost, merely to elicit money and applause from their spectators.

There are eleven muscles belonging to the palate and pharynx, which I will now briefly describe. 1st, Azygos uvulæ, in the centre of the velum pendulum palati, or that curtain which hangs at the back of the throat. There is a small depending pap or point of flesh called the pap of the throat. The azygos uvulæ is the only muscle belonging to this pap, and pulls it upward to keep it out of the way of the morsel about to be swallowed after mastication. 2d, Levator palati mollis arises from the os-petrosum, the Eustachian tube, and sphenoid bone, and spreads over the velum pendulum palati, or curtain of the throat. It pulls up the curtain when food is to be swallowed, and also prevents the food from passing up to the nostrils by spreading the velum or curtain backward, and protecting the passage. It also protects the mouth of the Eustachian tube, or internal opening of the ear, and prevents the food passing into it, so that hearing is unimpaired. 3d, Circumflexus palati arises from the sphenoid bone, and the beginning of the Eustachian tube, or internal opening of the ear at the back part of the mouth: it runs along the tube, and becoming tendinous, turns under the hook of the internal pterygoid process, and mounts again to the side of the curtain of the palate: its office is to pull down the palate, and by stretching it to make it tense. 4th, Constrictor isthmi faucium arises from the root of the tongue on each side, extends to the middle of the velum (or curtain), and terminates near the uvula. The semi-circle which this expansion describes forms the first arch that presents itself to the eye, when we look into the mouth. This muscle pulls down the curtain and elevates the root of the tongue, to meet the vail. 5th, Palato pharyngeus, forms the second arch of the throat, begins at the middle of the soft palate, extends round the entry into the fauces, and terminates in the wing or edge of the thyroid cartilage. The first arch belongs to the root of the tongue; the second arch belongs to the gullet. This muscle contracts the arch of the fauces, or gullet, and assists in closing it on the food passing down the œsophagus, on its way to the stomach.

I will now explain the pharynx. The pharynx is that opening of the gullet which hangs from the basis of the skull, and is attached to the occiput, or posterior bone of the head, also to the pterygoid process, and the back parts of the jawbones. It expands into a large capacious bag, for the free reception of the morsel of food about to be swallowed, and terminates in the œsophagus, or that tube by which the food is conveyed down into the stomach. The pharynx is bounded by the root of the tongue, and the arches of the throat. It lies flat and smooth posteriorly, along the bones of the vertebræ, or spine, over which it is placed. It is protected anteriorly, and partly surrounded by the cartilages of the wind-pipe. Its sides are embraced by the horns of the os-hyoides, or bone of the tongue, and it is covered with flat muscular fibres, arising from this bone and the cartilages. These fibres spreading round the pharynx are named its constrictors, because they embrace it closely, and force down the masticated food by their contractions. 6th, The stylo-pharyngeus (a long slender beautiful muscle) arises from the root of the styloid process, expands on the side of the pharynx, and extends to the edge of the thyroid cartilage. It raises the pharynx to receive the morsel, and then straightens and compresses it to push the morsel down, and by its hold on the thyroid cartilage, it commands not only the larynx, but the whole of the throat. 7th, Constrictor-superior, arises from the basis of the skull, the jaws, palate, and root of the tongue. It surrounds the upper portion of the pharynx, and is not one circular muscle, but rather two muscles divided in the middle, posteriorly, by a distinct rapha, or approximation of opposite fibres. 8th, Constrictor medius arises from the round point in which the os-hyoides terminates, and the cartilage of the os-hyoides, where its horns are joined to its body: it lies over the constrictor-superior, like a second layer: its uppermost point

touches the occipital bone, and its lower point is concealed hy the constrictor-inferior. 9th, Constrictor-inferior, arises partly from the thyroid cartilage, and partly from the cricoid, and by its oblique progression it also overlaps the lower part of the constrictor-medius. This constrictor-inferior, like the two former muscles, meets its fellow in a tendinous middle line; and when the morsel is admitted into the pharynx, hy the dilatation of its arches, it is pushed down into the œsophagus, by the united force of these three constrictor-muscles. 10th, The œsophagus is a continuation of the larynx, it lies flat upon the hack-hone, and is covered through its whole length hy a muscular coat, which is formed not of circular fibres, like the pharynx, but chiefly of fibres running according to its length. 11th, Vaginalis gulæ, is that muscle, which like a sheath surrounds the whole membranous tube of the œsophagus.

There are three muscles in the tongue: their thickness constitutes its chief hulk, and their action performs all its motions. 1st, The hyo-glossus arises from the whole length of the os-hyoides, and forms the side of the tongue: it rounds the back of the tongue, and pulls down its edges. 2d, Genio-hyo-glossus, arises by a narrow pointed origin hehind the symphisis of the chin, and as it proceeds towards the tongue, and the hase of the os-hyoides, spreads out like a fan, and (with its radii extending upward and backward) constitutes the greatest portion of the bulk of the tongue; for it plies in the centre, from the root to the tip, and its fibres having a radiated mechanism, cause the tongue to perform every possible motion. The fibres which proceed backward thrust the tongue out of the mouth, and the middle fibres make the tongue hollow in its centre, and elevate its tip and root. 3d, The lingualis is an irregular hundle of fibres, running according to the length of the tongue, and lying hetwixt the hyo-glossus, and genio-hyo-glossus: as this muscle is in the centre of the tongue, and unconnected with any bone, it is therefore called the lingualis, or muscle of the tongue. From these simple facts, we perceive that each fleshy fibre has its particular use, and that the Eternal has not only created, but wisely adapted it to fulfil its intended purpose, in the mechanism and functions of the animal economy, with unerring precision and perfect accuracy.

There are three muscles that move the scapula, or shoulder-blade, upward and backward. 1st, The trapezius, is one of the most beautiful muscles of the hody: the two conjoined, one on each shoulder, and on the neck, extend from the tip of the one shoulder to the tip of the other, and from the nape of the neck, down to the loins: when they reach the top of the neck, they hecome tendinous, and are named ligamentum nuchæ, or ligament of the neck. From this point down the neck, the trapezius does not lay hold of the spine, but does so when it reaches the two last vertebræ of the hack. It is implanted into more than one-third of the collar-hone, next the shoulder, into the tip of the acromion, or shoulder top, and the whole length of the spine, from which the acromion rises. But its fibres arising from along the neck and hack, and converging almost to a point, have very different effects, according to the different fibres that act. It moves and rolls the scapula, pulls the head hackward, bends the neck, and is a powerful muscle of respiration. 2d, Levator scapulæ, is a small thin slip of flesh, arising from the four or five uppermost vertehræ of the neck, hy three or four and sometimes five distinct heads. The heads join to form a thin flat stripe of muscle about three inches broad, which is fixed hy a flat thin tendon to the upper corner of the shoulder-hlade. This muscle pulls up the scapula when we shrug our shoulders. 3d, Rhomhoideus arises first from the three lower spinous processes of the neck, and is implanted into the hase of the scapula; and second, from the spinous processes of the first four vertehræ of the hack, and runs into the hase of the scapula. It has heen sometimes reckoned two muscles, the major and minor; hut most anatomists consider it only one muscle with two divisions. It raises the shoulder-hlade, and carries it hackward. The muscles that move the scapula forward, come from the breast; upward from the neck; hackward from the spine; and downward from the ribs.

There are three muscles that move the shoulder-blade downward and forward. 1st, Serratus major anticus, arises from all the rihs, and by distinct portions from each rih, and lies on the side of the chest. The distinct portions hetwixt the ribs are called digitations or fingers; but the chief part of the muscle lies under the shoulder-blade, where it is thick and fleshy, and forms part of the cushion on which the scapula glides. It terminates in the whole length of the line, called the hase of the scapula: when the entire muscle acts, it pulls the shoulder-blade downward and forward: when only the lower portions act, they pull the lower angle of the scapula forward: when the upper part acts along with the pectoral muscle, the tip of the shoulder is fixed and pulled towards the chest, and the lower corner of the scapula is rolled backward. But its most important action is to fix the scapula, expand the ribs, and perform respiration, or hreathing. 2d, The pectoralis minor lies under the pectoralis major, close upon the rihs. It sometimes arises from the third, fourth, and fifth rihs; sometimes from the second, third, and fourth; and sometimes only from the third and sixth. Its three digitations are very thick and fleshy, and converge into a smaller muscle, terminating in a point attached to the apex of the coronoid process. It pulls the coronoid process forward and downward, and rolls the shoulders. 3d, Subclavian muscle, arises hy a flat tendon from the cartilage of the first rih, and becoming flat and fleshy, runs betwixt the first rib and the collar-bone. It is inserted along the whole clavicle, beginning ahout two inches from the sternum, and pulls the shoulder downward. The shoulder-hlade is moved upward hy the levator scapulæ, and trapezius; hackward, hy the rhomboideus, and the middle portions of the trapezius; downward and hackward by the lowest order of fibres in the trapezius; downward and forward hy the serratus major anticus; directly downward hy the serratus, assisted by the subclavius; balanced by the trapezius; and directly forward hy the pectoralis major.

The arm is joined to the hody and moved hy numerous powerful muscles, and is fixed to the hreast hy the ligaments of the collar-hone. The muscles that move the shoulder-blade lie upon the trunk; those that move the arm lie upon the shoulder-hlade; those that move the fore-arm lie upon the arm; and those that move the hand and fingers lie upon the fore-arm. But as the arm requires easy circular motions, it has a multiplicity of joints to perform them. It has the wrist, for turning it round; the elbow, for its hinge-like motions; and the shoulder-joint, on which it rolls; and to assist all these, the moveahle shoulder-blade becomes the centre of their motions; for after a certain point of elevation, the motion of raising the arm is performed by the action of the scapula upon the trunk; when our shoulder-hone is raised to a horizontal position, it is checked by the acromion or upper part of the shoulder-joint which hangs over it; and if we elevate our arm still higher, the scapula rolls, turning upon the point of the clavicle, or collar-bone, and as it turns, it glides easily upon those muscles, which lie like a fleshy cushion hetwixt it and that part of the trunk over which it is so usefully placed, by the glorious Author and Architect of the universe.

## GEOLOGY.

### CHAPTER V.

CLASSIFICATION AND MINERALOGICAL DESCRIPTION OF THE STRATIFIED OR AQUEOUS ROCKS.

The term rock is usually applied to hard stony substances, occurring either in layers or in amorphous (1) masses. In geology, however, the term is applicable to all suhstances, without reference to their hardness or softness, which occur in large masses in the crust of the globe. Thus, granite, marl, coal, and clay, are equally entitled to the name. The propriety of thus fixing the definition of the term will appear palpable, if we take the fact into consideration, that there is every degree of hardness to be found in the various mineral compounds, from the most indurated quartz rock to the softest clay. When we speak, therefore, of rocks, it is to be understood it is of those substances which compose the stratified and unstratified masses found at, or near, the surface of the earth.

Rocks have been classed mineralogically into the siliceous, the argillaceous, and calcareous; as quartz or silica clay or lime prevail.

As to their nature and origin, they have been divided into the igneous and aqueous; the igneous being classed into the plutonic and volcanic, and the aqueous into the metamorphic or altered, and the fossiliferous.

Again, as to their comparative age, into the primary, the transition, the secondary, the tertiary, and post-tertiary or recent.

All these modes of classification will appear necessary when we take into consideration the causes for adopting them. The reasons for the first mode of classification must be abundantly evident from the observations made in the last chapter, with respect to the great predominancy of quartz or silica, clay, and lime, as the constituents of mineral bodies, and consequently of rocks.

Every one has heard of the nature of those masses of molten matter which issue from the craters of volcanoes, overflowing large tracts of the surrounding countries, and forming beds sometimes of very considerable thickness,—in short, that many districts are wholly, or almost wholly, composed of matter so formed. Such lavas generally arrange themselves round the volcano, and give it a conical form. The substances thus produced are denominated volcanic rocks. There are also rocks which yield every evidence of their having been once in a fused state, partaking of many of the characters of lava, and other volcanic rocks; but these occur in countries where there is no volcanic crater, and they frequently cover the regular stratified rocks to a great extent. These are considered to have issued from the inferior parts of the earth through openings, or fissures, and to have accumulated in immense masses at the bottom of the ocean, from which they have been subsequently upheaved. These are the whinstones, or trap rocks, of Scotland, England, Ireland, &c. They generally occur in irregular hilly ridges, and not in conical hills or mountains like those which have issued from the volcanic crater. This class of rocks is also denominated volcanic. We find also another class of rocks, but of similar composition, occurring in the form of walls or dykes in the stratified rocks, to which we ascribe a similar origin, and also denominate trap.

The plutonic rocks, consisting of granite, sienite, and some porphyries, are those which are of a crystalline structure like the volcanic rocks, though not so much so, but they are distinct from them inasmuch as though "they pierce through other strata, they never, or rarely, have been found to rest upon them as if they had overflowed." "As it is admitted," says Mr Lyell, "that nothing strictly analogous to these crystalline productions can now be seen in the progress of formation on the earth's surface, it will naturally be asked, on what data we can find a place for them in a system of classification founded on the origin of rocks. First, then, in regard to the plutonic class: a passage has been traced from various kinds of granite into different varieties of rocks, decidedly volcanic; so that if the latter are of igneous origin, it is scarcely possible to refuse to admit that the granites are so likewise. Secondly, large masses of granite are found to send forth dykes and veins into the contiguous strata, very much in the same way as lava and volcanic matter penetrate aqueous deposits; both the massive granite and the veins causing changes analogous to those which lava and volcanic masses are known to produce; but the plutonic rocks differ from the volcanic, not only by their more crystalline texture, but also by the absence of tuffs and breccias, which are the products of eruptions, at the earth's surface: they also differ by the absence of pores or cellular cavities, which the entangled gases give rise to in ordinary lava. From these and other peculiarities, it has been inferred that the granites have been formed at great depths in the earth, and have cooled and crystallized slowly under the influence of enormous pressure where the contained gases could not expand. The volcanic rocks, on the contrary, have also risen up from below, have cooled from a melted state more rapid, upon or near the surface. From these hypotheses of the great depth at which the granites originated, has been derived the term plutonic rock, which they have received to distinguish them from the volcanic."

The propriety of the terms *aqueous* and *igneous* must now appear sufficiently explicit to the reader, when applied, in the one case, to those rocks which, like lava, have been once in a state of fusion, and in the other, to those which have originated from sedimentary deposition at the bottom of water. The metamorphic rocks are those stratified deposits which have been altered from their original earthy condition into a crystalline or semi-crystalline texture by heat, such as gneiss, mica slate, clay slate, hornblende slate, &c. These rocks are also termed non-fossiliferous, because they have never been found to contain any trace of animal or vegetable remains; and also primary from the same cause,—it being concluded by some geologists that they were deposited prior to the creation of organic life upon the globe. They have also been termed the crystalline strata, from their being more of a crystallized structure than the newer formations.

The term primary has been objected to by Mr Lyell as improper; because he contends that even gneiss and mica slate may have been produced from the waste of previously existing strata, of which the monuments remain in the enormous accumulations of these rocks. And all remaining traces, obliterated by conversion into granite, he considers gneiss a passage from mica slate into granite, and mica slate now in the progress of becoming gneiss, and ultimately granite, may have originally differed very little from other sedimentary deposits. Mr Lyell has used much ingenuity, and no small labour, in endeavouring to build up this his favourite theory. He has certainly adduced facts to show that rocks of all ages, when subjected to igneous action, undergo a certain degree of metamorphism; but the evidence adduced from these has never, we confess, been able to show us that gneiss has not resulted from the debris of granites, and that mica slate has not been the product of decomposed gneiss, instead of *vice versa*, as his theory would lead us to suppose. In the mean time we consider the term primary a very good term for the non-fossiliferous strata, and use it as such only.

Transition is certainly a very objectionable term, as the strata of every period indicate what the term is meant to express—an alteration of condition. Yet no better has been yet suggested to designate the period between that of the introduction of marine animal life, to that of the creation of land animals, of which we have the first trace in the newest of the secondary deposits, namely, the new red sandstone: we therefore coincide with Dr Buckland in this use of the term. The term secondary comprehends all those rocks which are newer than the coal series, and older than the tertiary—the tertiary all those rocks which contain recent species of mollusca, and animals allied to the existing tribes, but which were deposited prior to the creation of the human species.

We shall now present the reader with a systematic arrangement of British strata.

## TABLE OF BRITISH DEPOSITS.

*Recent deposits and accumulations.*

Vegetable Soils—peat, mud, clay, sand, and gravel, deposited during the historic era, by rivers, lakes, floods, &c.

### STRATIFIED ROCKS.

*Tertiary strata.*

| | |
|---|---|
| Crag, 167 yards. | Upper Crag—Marine shells, pebbles, sand, &c.<br>Lower or Coralline Crag—Marine shells and corals in sand or coarse limestone. |
| Fresh Water Marls, 33 yards. | Upper Fresh Water Beds—Marly limestone and clay.<br>Estuary Beds—Marine and estuary clays.<br>Lower Fresh Water Beds—Marly limestone and clay |
| London Clay, 200 to 600 yards. | London Clay—Clay with shells, &c.<br>Plastic Clay—Variegated sands, clays, lignite. |

*Secondary strata—Cretaceous series.*

| | |
|---|---|
| Chalk Formation, 200 to 330 yards. | Upper Chalk—Soft white chalk with layers.<br>Lower Chalk—Hard white chalk with few or no flints.<br>Chalk Marl—Soft clayey chalk. |
| Green Sand, 160 yards. | Upper Green Sand—Green sand.<br>Gault—Blue marl or clay.<br>Lower Green Sand—Irony brown or green sands with limestone in some places. |

*Oolitic series.*

| | |
|---|---|
| Wealden Formation, 300 yards. | Weald Clay—Clays with calcareous or limestone beds occasionally interposed.<br>Hasting Sands—Sands, clays, and calcareous grits.<br>Purbeck Beds—Clay or marls, and beds of limestones of various kinds. |
| Upper Oolite, 130 yards. | Portland Oolite—Limestone and sands.<br>Kimmeridge Clay—Blue clay with septaria. |
| Middle Oolite, 150 yards. | Upper Calcareous Grit—Calcareous sandstone.<br>Coral Rag—Oolitic coralline limestone.<br>Lower Calcareous Grit—Calcareous sandstone.<br>Oxford Clay—Blue clay with septaria.<br>Killoway Rock—Calcareous sandstone. |

| | |
|---|---|
| Lower Oolite, 130 yards. | Cornbrash—Coarse limestone.<br>Forest Marble—Coarse limestones, sands, and clays.<br>Great Oolite—Oolitic compact, or sandy limestones.<br>Fuller's Earth—Limestones, clays, &c.<br>Inferior Oolite—Oolitic and ferruginеous limestones.<br>Sand—Calcareous or ferruginеous sands or sandstones. |
| Lias, 350 yards. | Upper Lias Shale—Blue laminated clay.<br>Marlstone—Sandy, irony, and calcareous beds.<br>Middle Lias Shale—Blue laminated clay.<br>Lias Limestone—Blue and white compact limestones.<br>Lower Lias Marls—Clays of different colours. |

*Saliferous or new red sandstone series.*

| | |
|---|---|
| Upper New Red Sandstone, 300 yards. | Variegated Clays—Red, greenish, and yellowish clays.<br>Red* and white sandstones, and conglomerates. |
| LowerRed Sandstone, 100 yards, or more. | Knottingley Limestones—Grey laminated limestone.<br>Gypseous Marls—Red and white clays containing gypsum.<br>Magnesian Limestone—Yellow granular and concretionary limestones.<br>Marl Slate—Laminated calcareous beds.<br>Red Sandstone—Red sandstones, clays, and conglomerates. |

*Transition strata—Carboniferous formation of the North of England.*

| | |
|---|---|
| Coal Formation, 1,000 yards. | Coal Group—Coal, sandstone, shale, ironstone, &c.<br>Millstone Grit—Sandstone, often coarse and pebbly, shales, and some thin seams of marine limestones and coals. |
| Carboniferous Limestone, 100 yards. | Yoredale Rocks—Limestone, sandstone, ironstone, and chert, and some coal beds.<br>Scar Limestone—Limestones, freestones, shales, and in Yorkshire some coal.<br>In Derbyshire, this formation, to the thickness of about 1,000 yards, consists almost solely of limestone. |
| Old Red Sandstone, 100 to 330 yards. | Conglomerate Group—Conglomerates and sandstones.<br>Cornstone Group—Coloured clays, sandstones, and concretionary limestones.<br>Tilestone Group—Flagstones and clays. |

*Carboniferous Formation of the West of Scotland.*

| | |
|---|---|
| Coal Formation, 1,000 yards. | Upper Red Sandstone—Red sandstones and clays, often variegated with some thin imperfect seams of coal.<br>Upper Coal Group — Coals, white sandstones, shales, blackband, or carboniferous ironstones, fresh water musselbands, &c.<br>Upper Limestone Group—Calm limestones and shales, with marine shells, thick grits, and fine sandstones.<br>Under Coal Group—Coals, fine white sandstones, carboniferous and clay ironstones, marine remains.<br>Clay Ironstone Group—Vast beds of clay, shale containing many beds of clay ironstone, and some impure limestones, marine remains.<br>Under Limestones—Limestones, coal, sulphureous shale, sandstone, conglomerates, and red marl, marine remains.† |

*Silurian series—Upper Silurian.*

| | |
|---|---|
| Ludlow Rocks, 660 yards. | Upper Formation—Micaceous grey sandstone, Aymestry limestone, clay limestone.<br>Lower Formation—Shale with concretionary limestone. |
| Wentock Rocks, 600 yards. | Wentock Limestone—Concretionary limestone.<br>Wentock Shale—Clay shale. |

*Lower Silurian.*

| | |
|---|---|
| Caradoc Rocks, 830 yards. | Caradoc Sandstones — Flags of shelly limestone and sandstone, and thick-bedded white freestone. |
| Llandeilo Rocks, 400 yards. | Llandeilo Flags—Dark-coloured calcareous flags. |

*Cumbrian series.*

| | |
|---|---|
| Upper Slate Formation, thickness unknown. | Plynlymmon Rocks—Argillaceous, indurated, and sandy slates, calcareous and argillaceous rocks.<br>Bala Limestone—Calcareous and argillaceous rocks, with marine remains.<br>Snowdon Rocks—Variously coloured and indurated slates, with a few marine remains.<br>Clay Slate—Soft dark slate. |

*Primary strata—Skiddaw series.*

| | |
|---|---|
| Lower Slate Formation, thickness unknown. | Chiastolite Slate—Soft dark slate, with chiastolite—no fossils.<br>Hornblende Slate—Soft dark slate, with hornblende—no fossils. |

* The Musselkalk—an interesting shelly limestone connected with the new red sandstone on the Continent, but is not found in England.

† The old red sandstone of Scotland is similar to that of England, and immensely thick. It consists of white, reddish, and coloured sandstones, alternating with red and variegated marls with cornstones: it presents an immense accumulation of conglomerates. The older members of the group are of a hard flaggy nature, and generally of a brownish or dark grey colour. The old red sandstone rests unconformably on greywacke and the schists to which it belongs. No trne silurian rocks have been described as occurring in Scotland. Between the old red sandstone and the under limestone group north of the river Clyde, there is an extensive formation underlying the trap range of Campsie, of thin compact limestones alternating with friable clay shale. In some places, from 50 to 60 beds of these limestones are seen in one escarpement. We have not been able to detect any organic remains in either the limestones or the shales.

*Mica Slate and Gneiss Rocks of Scotland.*

In this formation, mica slate and gneiss often alternate with each other, and the formation may be considered as made up of these rocks and other schists—mica slate prevailing in the upper, and gneiss in the lower divisions of the series; none of the beds contain organic remains, and are the oldest we have any knowledge of. They are much more extensively developed in the Highlands of Scotland, than in England or Wales, where with the non-fossiliferous schists they are probably more than twenty miles in thickness! offering an ample equivalent to the slates and silurian rocks of England and Wales.

Having furnished the reader with a tabular view of the different stratified formations, it may not be improper to describe in a few words the character of the more common stratified rocks; so that he may be able to detect them readily, when offered to his observation—after which we shall describe the igneous rocks.

The stratified rocks which it is necessary that the student of Geology should be able readily to recognise, are few in number, viz., gneiss, mica slate, clay slate, chlorite or talc slate, hornblende, slate, chiastolite slate, common limestone, marble, chalk, oolite, magnesian limestone, dolomite, flint, chert, sandstone in its different varieties, conglomerate, marl, gypsum, rock salt, shale, ironstone, coal, cannel splint, soft or cubical, anthracite, and lignite. With a knowledge of these, he will scarcely fail to be able to study any formation connected with the stratified portion of the crust of the earth; for that purpose, therefore, we shall give a short description of each.

Gneiss, like granite, is composed of mica or talc, felspar, and quartz. The mica occurs often in thin layers, with the felspar or quartz. Mica is of a dark greenish colour, with a silky lustre. The felspar is either white or grey, or of a fleshy colour. The quartz is commonly milk-white. The stone itself is highly indurated, and of a vitreous or crystalline appearance, and not to be distinguished from granite but by the crystals being rather mechanically than chemically arranged, and by its lamination.

Mica slate splits more readily than gneiss, and the cleavage is of a more silvery lustre. It is composed of scales of mica and fine grains of quartz. It is generally grey or greyish, but occasionally brown, and frequently contains garnets, which are supposed to have been produced through the agency of a greater heat than the other masses have been subjected to.

Talc, or chlorite slate is scarcely distinguishable from mica slate,—the principal difference in talc being the non-elasticity of its leaves or scales.

Clay slate is more homogeneous, but appears to be composed of nearly the same ingredients. It is the well-known article used for roofing houses—the finer varieties are used as writing slates, &c.

Hornblende slate differs also very little from mica slate. It is less glassy, and emits when breathed on, a disagreeable smell. It is of a very dark grey colour. All these varieties of slate occasionally contain iron pyrites in cubic crystals.

Chiastolite slate is so called from the presence of that mineral which occurs in cubes with the mark of a cross upon them.

Limestone is of every colour from white to black—it is readily known by effervescing readily, when muriatic or sulphuric acid is applied to it.

Marble is a granular variety of limestone—pure white, black, and often beautifully variegated with shadings and streaks of different colours, and sometimes ornamented with animal remains.

Oolite or roe-stone is of a yellowish white, or fawn colour, and is composed of little round concretions like the roe of a fish.

Magnesian limestone is of a yellow colour, and sometimes occurs in botroidal (grape-shaped), mammillated, honey-combed, and other concretionary forms. It is used in the construction of the new houses of Parliament, being admirably adapted for enduring the weather.

Dolomite is also a magnesian limestone, of a light fawn or yellow colour, in some parts of a crystalline, and in others of a concretionary character.

Flint is so well known as to require little description: it is a dark compact variety of quartz. Chert is allied to it, but of a less silicious character; chert is known also by the name of hornstone,—it having in some of its varieties the appearance of horn.

Sandstone is rather an indefinite term, as its name implies: it is composed of consolidated sand, whether that be of a silicious

or calcareous character. Sandstones are most frequently silicious when they are called freestones—they occur massive and laminated—in the latter case the lamination is generally owing to the presence of scales of mica, in which instance we have a laminated micaceous sandstone. Sandstones are white, grey, brown, red, green, and variegated in colour—conglomerates consist of the rounded or angular fragments of various rocks cemented together. A breccia is a conglomerate in which the fragments are all angular.

Marl is an English name given to loose clays containing lime, or to indurated masses of the same minerals; they are white, red, brown, green, yellow, or purple in colour.

Gypsum, or the sulphate of lime, is a substance having the appearance of statuary marble when massive, and is then called alabaster. It is frequently manufactured into mantel ornaments, &c. The fibrous varieties are called selenite. Gypsum is soft, and is scratched by the nail.

Ironstone is of different colours, grey, fawn, black and red; it is easily known by being attracted by the magnet when roasted. Blackband ironstones contain an admixture of coal, and are frequently streaked with a fawn-coloured variety. Clay ironstones are compact and generally dark-coloured, and have a brownish streak.

Cannel coal is a compact coal, in which the vegetable structure has not been destroyed. Splint coal divides horizontally into plates. Cubical coal is soft, and divides into rhomboids. Anthracite is a species of mineral charcoal, with a metallic lustre; when burnt, it emits no flame, but great heat.

Lignite is wood half-converted into coal,—the woody fibre being distinctly visible.

We have thus presented the reader with a view of the stratified rocks, as they occur in the crust of the earth. We trust it will be sufficient to enable him not only to follow out our future remarks intelligibly, but in some measure to commence practical Geologist himself. How many thousands lose the time which might be profitably spent in the examination of the archives of nature, as treasured up in the mineral masses of the earth in frivolous dissipation! There is scarcely a locality where there is not a quarry, a mine, a marl, or sand pit. All these afford opportunities of being acquainted, so far, with the ancient operations of nature; and where a country is variegated by river, streamlet, glen, or hill,—what a source of gratification does not the geologist possess in his rural ramblings! He there traces the slow and silent progress of time in effecting changes on the surface of the earth; and even from the small scale of operations he may witness, he learns to contemplate changes which it must have required myriads of ages to produce. The very pebble at his foot tells of the journey it has performed, and instructs him respecting the revolutions of a world! While so engaged, he imbibes health and vigour from the breeze, and in every little discovery he makes, he blesses the hour he became a geologist.

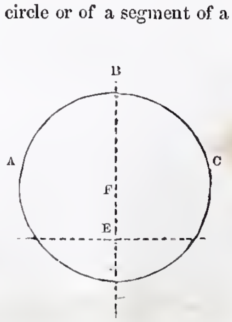
In our next, the classification and character of the stratified rocks will claim our attention.

## ILLUSTRATIONS OF MECHANICAL DRAWING.

### CHAPTER II.

Problem XI. To find the centre of a circle or of a segment of a circle.

*First.* For the centre of a circle.

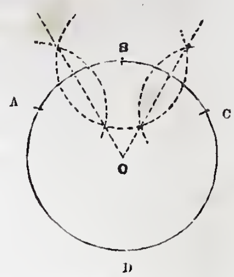



1. Let A B C D be a circle, of which the centre is to be found. Draw and chord A C.

2. Bisect the chord at E, and draw B D perpendicular to it, bounded both ways by the circumference. Then B D is a diameter.

3. Bisect B D at F; this point will be the centre of the circle.

Or, the following method may be adopted; and it is the more expeditious of the two.




1. From any point B in the circumference, with a radius not greater than that of the circle, describe a circular arc.

2. From two other points A and C, beyond this arc, one on each side, describe other arcs with the same radius, each cutting the first arc in two points.

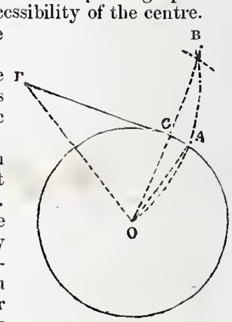
3. Through the two points of intersection thus found, draw straight lines meeting at the point O. This will be the centre of the circle.

*Second.* For the centre of a circular segment or arc. The second process for finding the centre of a circle may also be applied to find the centre of a segment. In the diagram annexed to the description of that process, if the segment A B C be given, its extremities A and C, and any intermediate point B, may be taken for the centres on which the curves are described, and the centre, O, will be found, as already explained. If the curve be greater than a semi-circle, as A D C, the same process is applicable; or if it be much greater, the first method may be resorted to. It is obviously of importance that the points A, B, and C, be well apart, and about equally distant too, and also that the arcs employed be of as large a radius as convenient, as the process is then likely to be more accurate.

Problem XII. To draw a tangent to a circle through a given point.

There are several varieties of this problem, depending upon the position of the given point, and the accessibility of the centre.

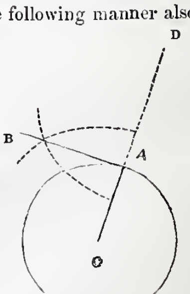
*First.* When the point is outside the circumference, and the centre given.




1. Let P be the point, and O the centre of the circle A. With the radius P O, on the centre P, describe the arc O A B.

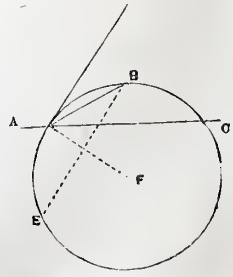
2. With the diameter of the given circle, as radius, on the centre O, cut the arc at B; join O B and bisect it at C. The line P C A will be a tangent to the circle, touching it at A. Here it may be observed that as the line P C A is perpendicular to O B, it is identical with the line employed in the process for bisecting the line O B; thus, there may be but one operation in performing this bisection, and drawing the line P A.

The tangent may be drawn in the following manner also. Draw B O to the centre; upon P O as a diameter describe a semicircle, cutting the circle in A; the line P A is the tangent.




*Second.* When the given point B is in the circumference, and the centre given.

1. Let A be the given point. Draw O A D, making A D equal to O A; and draw B A C perpendicular to it, and B A is the tangent required.




*Third.* When the centre is inaccessible, as the given point is in the circumference.

1. Let A B C be the given arc, and A the given point. Set off from A, two equal arcs A B, B C, and draw the straight lines A B and A C.

2. Make the angle B A D equal to the angle B A C. Then A D is the tangent.

This is a very simple operation, and it may be employed with advantage even though the centre be given.

Another mode is to set off on each side of the point A, equal

arcs A B and A E; to join E B, and to draw a perpendicular A F to it, and finally to draw A D perpendicular to A F.

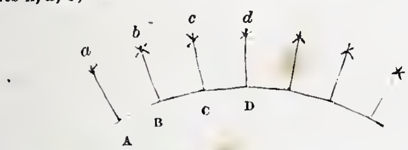
PROBLEM XIII. To describe a circle that shall pass through three given points.

The second process for finding the centre of a circle (Prob. XI.) is exactly applicable for this purpose. Referring to the accompanying figure, suppose A, B, and O, to be the three given points; the point O being found by the method there delineated, it is the centre of the circle required, and by taking the distance, to any of the points A, B, C, as a radius, the circle may be described passing through all the three points.

Also this problem is obviously identical with that which requires to circumscribe a triangle, as in this case a circle is to be described passing through the three points terminating its angles; the problem which proposes to describe an arc of a circle passing through the extremities of a straight line with a given *rise*, is but another form of the one now discussed. For example, in the figure accompanying the first process under problem XI, if A B be the straight line, and E D the given rise, being a perpendicular to it at the middle point E, it is clearly a case of the 12th problem; as we have the three points A, B, C, and we wish to describe an arc, passing through these three points. This problem will be useful for finding the diameter of a fly-wheel, or any other object of large diameter when only a part of the circumference is accessible.

PROBLEM XIV. To draw a number of radial lines upon the circumference of a circle, the centre being inaccessible.

1. If the radii are at equal distances, divide the circumference or a part of it, into the required number of equal parts, at the points A, B, C, &c.




2. On the points A, B, C, &c., as centres, with radii larger than a division, describe arcs cutting each other at *b c*, &c.; thus, from A and C as centres, describe arcs intersecting at *b*; from B and D as centres, describe arcs cutting *a c*; and so on. The lines A B *b*, C *c*, &c., will be radial lines as desired.

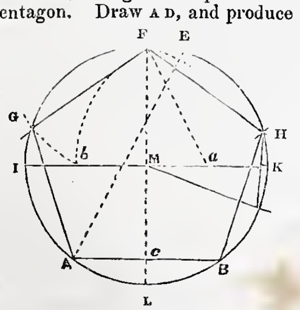
In presenting the foregoing methods of performing geometrical operations, no account is taken of the use that might be made of the common T square, and the triangles, or of the parallel ruler. These instruments will, however, where applicable, assist considerably on many occasions, in simplifying the solution of the problems, and with an accuracy generally quite sufficient for practical purposes. When, for example, a tangent is to be drawn to a circle through a given point in the circumference, one edge of the triangle might be set to the radius at that point, and the parallel ruler set to the perpendicular edge of the triangle, and then shifted to the circumference, where the tangent could be drawn, or, if the tangent be parallel to an edge of the board, the T square will suffice to draw it.

PROBLEM XV. On a given line to describe a regular pentagon.

1. Let A B be the given line, bisect A B at C, and draw C F perpendicular to A B. Set off on this line, a length C D equal to A B the given side of the required pentagon. Draw A D, and produce it indefinitely, make D E equal to half A B. From A as a centre, with the length A E as a radius, describe the arc E F, cutting C F in F.

2. From A F and B as centres, with A B as a radius, describe arcs cutting each other in A & H.

3. Draw the lines A F and H B, when A G F H B will be the pentagon required.

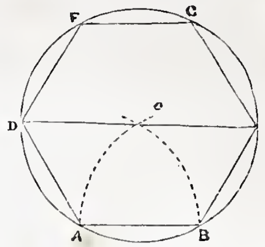



PROBLEM XVI. To describe a pentagon in a given circle. Let A G F H B be the given circle.

1. Draw the diameters I K and L F perpendicular to each other; bisect M K in *a*. Upon *a* as a centre, with the distance *a* F, describe the arc F *b*. Upon F as a centre, with the distance F *b* describe the arc *b* G, cutting the circle at G. Join G A and carry it round the circle five times, and it will produce the required pentagon. The arcs contained between the extremities of any side of the pentagon, as H K, being bisected as at H K, will give the side of a decagon or ten-sided figure, inscribed in the same circle.

PROBLEM XVII. To construct a hexagon on a given line.

1. Let A B be the given line. On the extremities of this line, with the extent of the line as a radius, describe arcs intersecting each other at C.



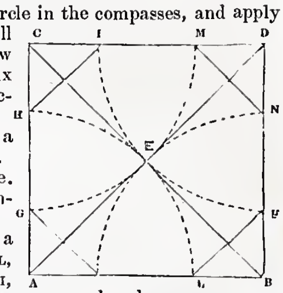

2. On C as a centre with the same radius, describe a circle. From the intersections at D and E with the arcs before described, set off D F and E G on the circle,

3. Join A D, D F, F G, and E B, which will form the hexagon required.

This figure is one which is often required in delineating machinery, as for instance in setting out plan views of bolt-heads, &c. For this purpose, the T square and an angle of 60° and 30° are useful; or when the circumscribing circle is given, the following method may be substituted.

Take the radius of the given circle in the compasses, and apply it to the circumference, which will divide it into six equal parts. Draw a chord to each arc, and the six chords will form the hexagon required.

PROBLEM XVIII. To inscribe a regular octagon in a given square.




Let A B C D be the given square. Draw the diagonals A D and B C intersecting at E.

Upon A B C D as centres, with a radius E C, describe the arcs H E L, K E N, M E G, and F E I. Join K G, H I, M N, and F L, and the required octagon is produced.

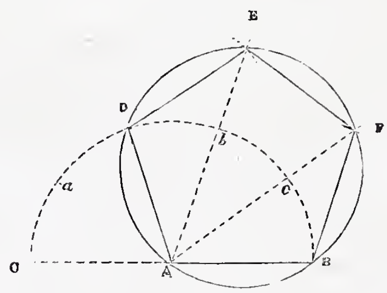
If a circle is given, in which to inscribe a regular octagon, it may be done in the following simple manner:—

1. Draw two diameters at right angles to each other.

2. Bisect the four arcs thus obtained, and draw chords to each: which chords shall form the octagon required.

PROBLEM XIX. To describe any regular polygon upon a given line.

Let A B be the given line. Produce A B any length in either direction, as A C. From A as a centre, with A B as a radius, describe a semicircle, divide it into as many equal parts as the polygon is to have sides; in the present instance we have chosen five, as *a* D *b c*, the number of points required to produce a pentagon.




2. Draw lines through all the divisions, (minus one) as A D, A *b* E, A C F.

3. From D and B as centres, with A B as a radius, describe arcs, cutting A E in E, and A F in F. Draw the lines D E, E F, and F B; when A D E F B shall be the polygon required.

## BAIN'S ELECTRIC TELEGRAPH.

AMONGST the overwhelming number of inventions which so markedly characterise the present age, there are few which so well deserve the fostering care bestowed upon them, because few promise so well to repay it by their subserviency to the wants and demands of society, as the Electric Telegraph.

Historical accounts of the different inventions and modifications of inventions which have been devised under this name, have so

often been brought before the public, that it would amount to a mere repetition were we to do more than refer to the fact, that the apparatus, from being highly complex and expensive, has at length been reduced to a degree of simplicity and completeness beyond which we can hardly conceive room for improvement. In the present instance, it is our business to describe one of the most successful examples of telegraphic apparatus in use at the present time: we refer to that erected by Mr. Alexander Bain upon the line of railway connecting Edinburgh and Glasgow. Mr. Bain is already favourably known to the scientific world, by his two peculiarly happy and ingenious inventions, the Electric Printing Telegraph, and the Electric Clock, illustrations of which will be given in a subsequent article; but without depreciating these valuable contributions to the arts and to science, it seems to us that the Signalling Telegraph, which he has brought to the verge of completeness, will do more to enlarge his fame than all his previous labours. In this he has been equally successful and more useful.

One of the distinguishing peculiarities of Mr. Bain's practical application of electricity to telegraphic purposes, is the method by which he causes the deflection of the electro-magnet by the current of electricity. In all previous arrangements of this nature, the connecting wire is placed parallel with the magnet; but Mr. Bain, by repeated trials, has ascertained that a much greater amount of disposable electric force may be realized, *cæteris paribus*, by placing the wire at right angles to the magnet. A striking example of the superiority of this disposition of the component parts of the machine, is to be seen at the Glasgow station of the Edinburgh and Glasgow railway. Here, for a distance of a mile and a half, a six-wired telegraph of Messrs. Cook and Wheatstone runs side by side with Mr. Bain's single wire. The quantity of power required to work the former for this short distance is 12 pairs of plates, while, for the whole 46 miles of Mr. Bain's, only 16 pairs are required—which amount of power is found to answer every purpose. The apparatus is in actual operation, and signals are transmitted with great facility and correctness.

As before mentioned, the medium of connection between the two termini of the railway, is a single iron wire (No 9,) coated with zinc, as a protection against the action of the atmosphere. It is supported on timber posts, to which it is attached by means of a peculiarly constructed insulator which answers the double purpose of confining the electric current to the wire, and assisting in tightening it, thus dispensing with every species of winding apparatus formerly proposed for the latter purpose.

*Description of the Apparatus.*

Figs. 1 and 2, Plate 11, represent front elevations of the telegraphic apparatus, which is placed at each terminus, as well as at the intermediate stations of Ratho, Linlithgow, Falkirk, Castlecary, Kirkintilloch, and Cowlairs. The same letters of reference apply to the same parts in all the views.

A A is a mahogany case, the front being removed for the purpose of exposing the internal mechanism to view. B, B, is a dial-plate having the characters I and V engraved upon it. C, C, are reels of thin copper wire fixed to the brass frame E, E, which is screwed to the back of the case. D, D, are two semicircular steel magnets attached to the brass arm C, C, which is freely suspended on an axis at 3. T, T, is a brass sliding bar provided with a detent Z. U, is a wooden support attached to the wall for the purpose of sustaining the bell V, the hammer of which, W, turns upon a centre at X, and is attached to the sliding bar T by means of the wire Y.

M, is the voltaic battery of 16 pairs of plates, Z being the zinc and C the copper electrode, the wires from which, 4 and 10, are attached to the binding screws 11 and 12. O, O, is a wooden block having inserted on its surface the pieces of brass, R, R, I, and P, P. C, C, are two spiral springs attached to the handle F. N, N, are the springs attached to the handle for the purpose of keeping it in its central position when the instrument is out of action. A, I, are the conducting metals buried in the earth at each terminus, for conducting the current of electricity into and out of the earth.

To illustrate the action of the apparatus we shall suppose it is required to send a message from Edinburgh to each of the stations along the line. The first movement will of course be to give notice to the keepers of the different stations, so that they may be in readiness to receive the intended message. In order to do this, the handle F is to be moved to the right as shown in fig. 1; this action will cause a current of electricity to pass from the battery M, at Edinburgh, along the wire to the binding screw 12, and from thence by the wire 4, to the lower piece of brass, R; and through the wire shown in dotted lines to the upper brass II. Thence by the upper spring C to the upper brass P, and by the wire attached to it, to the bobbins C C, whence it is conducted to the binding screw, 8, to which is attached the main wire connecting the two termini, so that by this means it reaches the instruments placed at all the stations. From the instruments at Glasgow it passes to the ground, and is conveyed back so as to complete the circuit, by the moisture of the intervening 46 miles of ground. The action of the electric current on the steel magnets, in its passage, causes the indices Q D of all the instruments to move to V, by an arrangement which we shall explain more clearly hereafter.

When the instruments are inert, the hammers of the alarm bells are kept set, by means of the following arrangement:—The left-hand end of the lever 8 is drawn downwards, so as to raise the right-hand end until it rests on the axis of the index Q, a notch being cut out of it to let it pass. The sliding piece T is now drawn down until the detent Z catches on the lower side of the axis of the lever; this action raises the hammer W, which remains in this position until the indices Q are moved to V; as already mentioned, the lever 8 then becomes clear of the axis of the index, and the right-hand end being the heaviest, falls down, which action in a similar manner relieves the slide T, so as to allow the hammer to descend and strike the bell, thus drawing the attention of the station-keeper to the instrument.

In proceeding to transmit a signal, it is to be understood that if the handle F is moved to the left, the index will point to I, if to the right, it will stand at V, as before stated. By transposing these simple movements, the whole of the signals may be transmitted. Thus, for instance, supposing it is required to give the letter A, the handle F is to be moved to the left, and the index of course stands at I, which, according to the table C, C, indicates A. To give the letter B, the handle must be moved twice to the left; and for C, three times, as explained in the table. The letter L, for instance, is indicated by moving the index twice to I, once to V, and once again to I; in this manner, words and sentences may be transmitted with great precision and speed.

The arrangement of the signals is such that all those on the left side of the index begin with I, and those on the right with V, so that as soon as the observer sees the index move, he knows immediately on which side to find the signalled letters. The mode in which numbers are distinguished from letters, is by allowing the hand to pause a little at the last character of the signal; for instance, in signalling the number 8, the index would be first made to stand at V, and then moved to I three times, being allowed after the last movement to pause for a second or two.

The method of signalling, as above detailed, is that used for transmitting general intelligence; but for the purpose of dispatching messages, connected with railway operations, the large table, B, B, is provided. Upon the upper end of the table, a series of signals are arranged which, given singly, are used to indicate the position of the trains upon the line, at whatever part of it they may be. Thus, when a train leaves Edinburgh, it is telegraphed throughout the line by the signals II, being given by the station keeper at the instant of departure. When the train arrives at Ratho, III are given by the station-keeper there, and so on until it reaches its destination. The method of indicating to the different station-keepers, the particular one with which it is intended to communicate, will be understood from the following description. It will be seen by reference to the table B, that all the signals at the top end with I, besides which there is another series ending with V. Therefore, at the moment when it is intended to communicate with any particular station, the station-keeper at that place is warned that the message is intended for him by a peculiar arrangement of the signals ending with V; thus, supposing the authorities at Edinburgh wish to communicate with the officials at the Falkirk station, although the alarm-bell would be rung at all the stations along the line, yet immediately after this has taken place, and the signals V V been given, indicating that the intelligence is from Edinburgh, the signals IVVV would be given, meaning that it is intended to be received at Falkirk.

Another method of using this table is to signal one of the characters at the top, ending with I, and another at the side ending with V, thus the intelligence meant to be conveyed will be found at the point of intersection of the two; for instance, if II are given at the top, and VV at the side, the question would be, WHAT IS THE CAUSE OF DELAY? All the squares upon the table are to be filled up with such questions and answers as experience may suggest.

Fig. 3 is a side view, and Fig. 4 of the same mechanism.

In Fig. 5, the point of the lever 8 is shown resting upon the axis of the magnets, the white portion of the circle being cut away, so that when the axis turns partly round it liberates the detent Z, and consequently the slide T is forced up by the weight of the hammer, which falls and strikes the bell.

BAIN'S PATENT ELECTRIC TELEGRAPH.

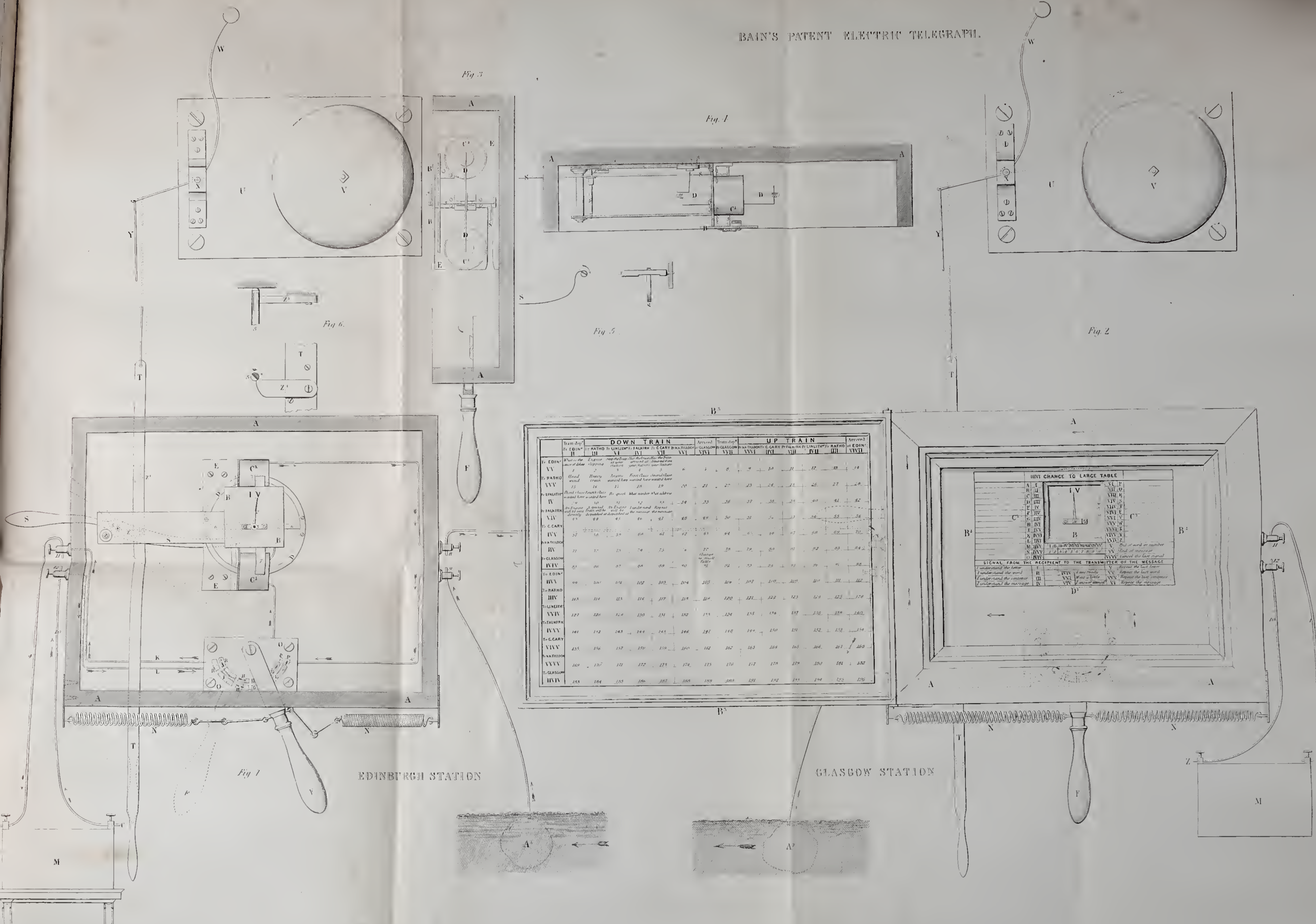
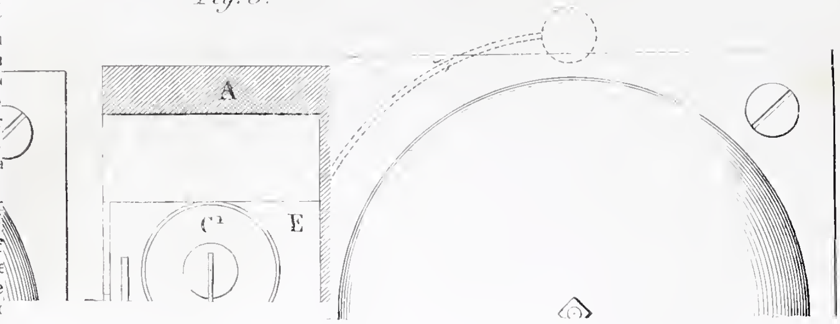


Fig. 3.



## PROFESSOR MORSE'S ELECTRIC TELEGRAPH.

The magneto-electric machine was originally contrived by Mr Saxton, soon after the commencement of the interesting discovery of Faraday, that magnetism was capable of exciting electricity. The conditions necessary for obtaining electricity in this way, were, chiefly, the disturbance of magnetic forces in a bar of soft iron, thus surrounded, to approach to, and recede from, the poles of powerful magnets; but the ingenuity of Mr Saxton far exceeded them all, by giving to the coils and enclosed bar a rotary movement about the poles of a U-form magnet. This instrument afforded bright sparks and strong shocks; but the currents of electricity thus obtained could not be converted to any useful purpose, as, in half revolution of the coils, the currents were in opposite directions. In 1838, Professor Page published in Silliman's Journal an account of an improved form of the machine, doing away with many existing objections, and furthermore rendering it at once a useful instrument, by a contrivance for conducting these opposite currents into one channel or direction, which part of the contrivance was called the unitress. The current produced in this way was capable of performing the work, to a certain extent, of the power developed by the galvanic battery; and the machine was found adequate to the furnishing of shocks for medical purposes, for exhibiting the decomposition of water, furnishing the elements, oxygen and hydrogen, at their respective poles, and producing definite electro-chemical results. These two last results could not be obtained without the aid of the unitress. But, with this improvement, the instrument was still wanting in one property of the galvanic battery, viz., that property which chemists call quantity, or that power upon which depends its ability to magnetize, and also to heat platinum wires. This last property has been given to the machine by the recent contrivance of Professor Page. The machine, in its novel construction under his improvement, developed what is called, by way of distinction, the current of intensity, but had a very feeble magnetizing power. By a peculiar contrivance of the coils, (not to be made public until his rights are in some way secured), the current of quantity is obtained in its maximum, while, at the same time, the intensity is so much diminished, that it scarcely gives any shock, and decomposes feebly. It has been successfully tried with the magnetic telegraph of Professor Morse, and operates equally well with the battery. It affords, by simply turning a crank attached to the machine, a constant current of galvanic electricity; and as there is no consumption of material necessary to obtain this power, it will doubtless supersede the use of the galvanic battery, which, in the event of constant employment, would be very expensive, from the waste of zinc, platinum, acids, mercury, and other materials used in its construction. It particularly recommends itself for magnetizing purposes, as it requires no knowledge of chemistry to insure the result, being merely mechanical in its action, and is always ready for action without previous preparation; the turning of a crank being the only requisite when the machine is in order. It is not liable to get out of order; does not diminish perceptibly in power when in constant use, and actually gains power when standing at rest. It will be particularly gratifying to the man of science, as it enables him to have always at hand a constant power for the investigation of its properties, without any labour of preparation. We notice among the beautiful results of this machine, that it charges an electro-magnet so as to sustain a weight of 1000 pounds, and it ignites to a white heat large platinum wires, and may be used successfully for blasting at a distance; and should government ever adopt any such system of defence as to need the galvanic power, it must supersede the battery in that case. Professor Page demonstrates, by mathematical reasoning, that the new contrivance of the coils affords the very maximum of quantity to be obtained by magnetic excitation.

The electro-magnet is the basis upon which Morse's invention rests in its present construction; without it, it would entirely fail. The electro-magnet is produced by the coiling around a bar of iron, made in the form of a horse-shoe, fig. 1, copper wire previously covered, similar to bonnet-wire, and varnished to prevent metallic contact with each other and the iron. The two terminations of the wire thus surrounding the iron in a spiral form, are brought out at each end of the curved bar, and are connected, one with a zinc pole of a galvanic battery, the other with a platinum; the battery being prepared in the usual manner with its corroding acid, produces galvanic electricity, which starts off one pole of the battery, follows the wire around the soft iron, and returns to the other pole of the battery by the other wire—thus performing a complete circuit. The galvanic fluid is now passing the whole length of the wire, and, while thus passing, the curved iron becomes a strong

Fig. 1.

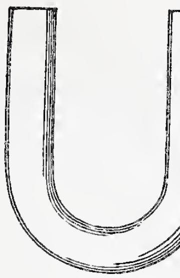
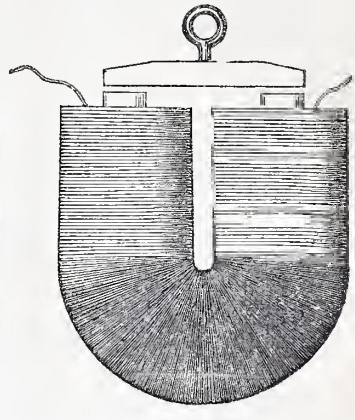


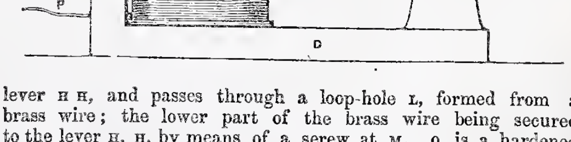
Fig. 2.



magnet. By connecting the two ends of the bent iron with a bar of similar soft iron, it will support many pounds weight. If, while in this condition, one of the wires is removed from the battery, the cross-bar falls, and with it its weights. The curved iron returns instantly to its original state. It is unmagnetized. Complete the circuit, as at first, and in an instant it is again a magnet. If the battery is placed 100, or 1000, or 10,000 feet from the magnet, yet, when the one is connected with the other by intervening wires, the effect upon the magnet is the same—making it a magnet when the circuit is complete, and *vice versa* when it is broken. In this way, the power is produced at a point of considerable distance from the generating agent, and is wholly at the command of the operator at the battery to take or destroy the power produced, with the utmost possible rapidity.

Figure 3 represents the most simple form of the electro-magnet, with its appropriate machinery for telegraphic purposes. A, represents a side view of the bent iron bar, surrounded with its coils of copper wire, standing upon a platform D. V, is an upright arm secured to D, to which the magnet, or soft iron, is permanently fastened by means of the bolt B B, passing between the prongs of the curved iron and through the board V, and adjusting screw C. E, is the projecting prong of the iron, after it has passed through the coils, one only being seen. The other prong is directly behind E. G, represents the end of the iron bar or keeper, extending back so far as to cover both the projecting ends of the horse-shoe formed magnet. This iron bar or keeper is fastened to the lever H H, which is delicately adjusted, so as to rise and fall on a pivot at I. K, represents a steel spring over the

Fig. 3.



lever H H, and passes through a loop-hole L, formed from a brass wire; the lower part of the brass wire being secured to the lever H, H, by means of a screw at M. O, is a hardened steel point, similar to those used by manifold letter-writers, and is also connected with the lever H, H, and directly over the centre of the metallic roller T, in which a slight groove is made to correspond with the point of O. R, represents the standard in which the axis of the roller T freely revolves, and is a part of D. The

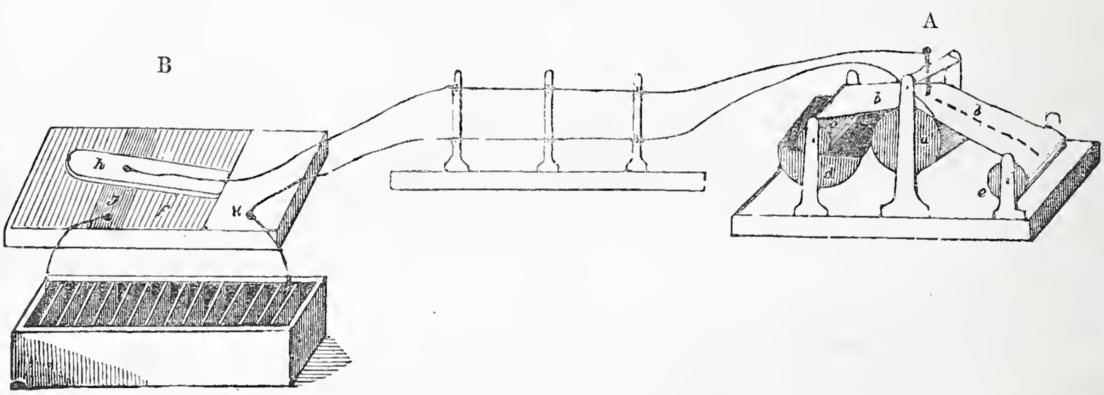
line S, represents the paper, in form of a ribband, passing from its coil between the roller and the point of O. N, and P, are the two extremities of the wire upon the magnet A. Every part is now described; and, from what has preceded the description, bearing in mind the effect of the battery when in action upon the soft iron, by forming a complete circuit with the wires N and P, the mode of writing by the instrument may be easily comprehended by what follows. Complete the circuit, and instantly the cross-bar G approaches the ends of the *magnet* E, until they meet in the direction of the arrow W. Break the circuit, and G is carried up in the direction of arrow X, by means of the spring K. If to the roller T, clock-work is attached, to give it a uniform movement upon its axis, the paper S, will move with the same uniform motion under the point O; then, by completing the circuit, the point O, is brought down upon the paper, which is indented to such a degree as to make it perfectly apparent, and continues to mark it in that manner so long as the circuit is closed; but, upon breaking the circuit, the marking ceases, and the point O, flies from the paper, which continues passing on. If the circuit is closed and broken with the utmost rapidity, then a succession of dots and spaces upon the paper appears. If the circuit is successively closed and broken with less rapidity, short lines and intervening short spaces are made. If closed for a longer time and broken in succession, then the marks become longer; so that dots, short lines, long lines, and short or long spaces, are made, according to the time the circuit is closed, and the rapidity with which the paper moves under the pen. An arbitrary arrangement of these dots, short and long spaces and lines, constitutes the telegraphic alphabet; by means of which, intelligence to any extent is communicated. Thus, one dot may represent A, two dots B, three dots C, one dot and a line D, &c. The paper to be imprinted is fixed upon a revolving cylinder, and records despatches day and night; and this without ink, as the impressions are easily read even by the blind. The records of the night continue entered on the morning. The alphabet is easily learned.

## DESCRIPTION OF THE ELECTRO-CHEMICAL TELEGRAPH.

The Electro-Chemical Telegraph, invented by Mr. Robt. Smith, Lecturer on Chemistry, Blackford, is an improvement upon his Voltaic Telegraph.

In the annexed wood-cut, A represents the indicating portion of the telegraphic apparatus, *a* is a leaden cylinder fixed upon a spindle, which is supported so as to revolve freely, by two standards attached to the bottom plate of the apparatus, *b b* is a piece of calico in the form of a ribband coiled upon the roller *c*, placed in the trough *d*, its contrary extremity being attached to a second roller *e*, revolving loosely in standards attached to the opposite end of the bottom plate, B is the communicator, or that portion of the apparatus through which any given signal is communicated to the indicator A; *f* is a block of wood having a brass plate *g* attached to it, *h* is a slip of wood hinged to the block, and slightly raised above the surface of the brass plate *g* by means of a spring placed beneath it. The brass plate *g* is connected by the wire *k* with the positive end of the voltaic battery C, the negative end of which is connected with the wire *l*, which passes along to the indicator A, where it is attached to the leaden cylinder *a*. The other wire *m* is attached to the finger board *h*, through which it passes, projecting slightly on the lower surface, its contrary end being attached to the impress wire *n*, which is supported loosely by a cross-beam on the top of the centre standards of the indicator, its lower end resting upon the calico ribband on the leaden cylinder beneath.

To put this apparatus in action, the cells of the battery C are filled with water, and the trough *d* with a solution of ferro-cyanate of potass, to which have been added a few drops of nitric acid. The roller *e* to which the indicator cloth is attached is next put in motion by clockwork, and thus the cloth wet with the solution contained in the trough *d* is caused to pass uniformly over the leaden cylinder *a* below the point of the impress wire. The apparatus is




now ready for signalling, which is done by pressing down the finger board *h*, so as to bring the end of the wire *m* in contact with the brass plate *f*, thus completing the electric circuit. The impress wire *n* now becomes the positive electrode, and the cylinder *a* the negative one, and a blue mark is printed upon the cloth, by the electric fluid decomposing the ferro-cyanate of potass, thus forming cyanate of iron. If the circuit is formed and broken rapidly, a succession of dots will be printed upon the cloth; if formed and broken at longer intervals, the result will be a series of marks. In this manner long and short spaces and corresponding lines will be formed according to the duration of the opening or closing of the circuit, and the speed with which the cloth is caused to pass beneath the metallic pen. An arrangement of these various marks thus forms the telegraphic alphabet, from which, sentences may be composed, embracing any information which it may be necessary to transmit. For instance, a single dot may be taken as the index for A, two for B, three for C, and a dot and line for D, &c.

The species of battery which is the best adapted for producing the electro-chemical indications, consists of 40 repetitions of charcoal and zinc plates; the charcoal plates being composed of three parts pulverized charcoal, two of pulverized coke, and one of wheaten flour, mixed together with water; when formed, the plates are allowed to dry, and are then placed in an earthen crucible, in the lid of which is an aperture for the escape of the gases; in this they are heated to redness. This battery will keep up a uniform and energetic current for a considerable time, the cells being merely filled with water; the only attention which it required subsequently, being to wash off any oxide which may be deposited upon the plates, and supply fresh water. The battery employed for making the electro-magnetic telegraph is a calorimeter or single circle, the electricity generated by this battery has a tendency to weaken in its progress, so that the defect must necessarily be provided for by placing batteries at different distances, according to the desired amount of power, this objection is completely removed in the voltaic apparatus. Experiment has proved that the electric energy from the intensity battery, in producing the electro-chemical effects, *increases* instead of diminishing in regard to distance. Faraday ascertained that the quantity of electricity required to decompose a single drop of water, is equal to that of a

powerful flash of lightning, while from the largest single circle ever constructed, not the slightest chemical effect can be exhibited. On the other hand, a small single circle, composed only of a few square inches of copper and zinc, will temporarily magnetize a large bar of iron, while a powerful voltaic trough will not magnetize a lady's sewing needle. Throughout the whole of the practical details of the electro-magnetic apparatus, a far greater amount of carefulness of workmanship is required than in those of the voltaic one. Thus, the whole of the joinings of the conducting wires require to be in perfect metallic contact, and carefully isolated, whilst the electro-chemical communications may be transmitted through the medium of a wire fence. The inventor lately exhibited an experiment which proves the practicability of this application.

In this case, the communicator and indicator were attached to the contrary extremities of an iron wire fence of a length of 1868 yards, when a number of signals were despatched with the greatest facility. This economical adaptation will doubtless render it worthy of the attention of railway proprietors, as a metallic fence may in this manner be rendered doubly useful.

## DOMESTIC MEDICINE.

MEDICINE is defined to be that science which treats of the means most effectual for the prevention of disease, and for removing it when it does actually exist. The first part of this definition will be chiefly kept in view in the following article, which is intended to be more of a chart, to point out the various rocks and shoals on which a strong constitution may be injured, or a weak one shattered to pieces, to guide the frail bark in safety over the sea of life to the desired haven of "green old age," than to encounter the difficult task of saving it after being engulfed in the whirlpool of disease. This, in our opinion, is the only legitimate object of a treatise on medicine, written expressly for the benefit of the non-professional reader. The curing of disease is completely beyond his province. To attempt such a thing would be to act the part of a blind man with a club, who, hearing a struggle between nature and disease, deals random blows around him. If he strikes disease, he kills disease; if he strikes nature, he kills nature. Let us leave the curing of diseases, therefore, to those who have spent a lifetime in acquiring a knowledge of them; who thoroughly know the mechanism and intimate structure of our bodies; who are perfectly acquainted with the different properties of remedies, and the various modes of applying them; and who can bring the light of science to bear upon the practice of their profession.

### CHAPTER I.

#### HISTORY OF MEDICINE.

At first sight a person may be apt to think a sketch of the history of medicine a dry and uninviting subject. He has probably heard of Esculapius, Hippocrates, Galen, Harvey, Sydenham, Boerhaave. He has some faint idea that they were great names in medicine; but at what age they lived, or what peculiar claims they have upon the grateful remembrance of posterity, he has not the most remote conception. The history of medicine is so intimately connected with the history of literature in general, the progress of civilization, the development of the human mind, that it cannot fail to be interesting to every inquiring member of society; a view of the various phases which the science has assumed, is both useful and instructive, as showing that from some of the false notions of the ancient physicians have arisen many of the popular errors respecting disease and the causing of it, that exist at the present day.

In the first ages of the world, man chiefly led a pastoral life. He was subject to few of those laws which civilization has now imposed upon society; he was in a great measure left to follow the instincts of nature, as to his eating and drinking, and other habits; his tastes were as yet uncorrupted by luxury, and his constitution unimpaired by vice; it is not then to be wondered at that his diseases were very few and very simple. To show us that they were far from having attained that complexity of character which now calls for the utmost skill of the physician, we have only to look at the present condition of man in his primitive state. In the "far west" of North America, where the country is still in the quiet possession of the Red Indian; where the foot of the white man has scarcely yet trod; where the contaminating influence of civilization has not yet poisoned the atmosphere, and infected the natives with habits of intemperance and other vices, the savage enjoys an extraordinary immunity from disease. Even from the very curse that was originally pronounced on Eve and her daughters, woman in her natural state seems almost exempt. In the frequent marches from one part of the country to another, the women and children of an Indian tribe are placed in the rear; and it is no unusual thing to see a female, when about to give birth to a child, step aside accompanied by another female, bear her child, bundle it up, and again overtake the marching tribe; so little is she influenced by those pains which are well known to be more severe, the more artificial the life of the woman.

During the patriarchal ages of the world, the history of the art of medicine is lost in mystery and fable. But however few the diseases, and however simple the remedies employed in these early times, we have reason to believe that considerable attention was paid to the healing art; for in the most rude and barbarous nation that has ever yet been discovered, a system of medicine, and a knowledge of a number of remedies, have been found. The art of surgery was undoubtedly the first branch of medical science that was cultivated, and the department chiefly followed by the most ancient physicians; very probably from the circumstance, that man in an uncivilized state would be frequently exposed to wounds and bruises, that his attention would thus be directed to the use of means for stopping the flow of blood, for protecting the wound from the air, and so forth. By-and-by he would have recourse to some expedient when affected with internal pain. Remedies would thus be tried at random; some would fail; others would succeed; experience would be gained, and in this manner would the art of physic gradually come into existence.

It was a notion universally prevalent amongst heathen antiquity before the days of Hippocrates, that the origin of disease was to be attributed to the anger of the gods, and means were therefore adopted to appease their wrath. In these circumstances the priests were had recourse to; and hence we find, among all the ancient nations, religion and physic combined, and the priests the only physicians. The Egyptian priests, at a very early period of the world's history, possessed almost all the knowledge of the arts and sciences that then existed. They, moreover, did not neglect the science of medicine; but they surrounded it with such impenetrable mystery, that they made much greater use of charms and incantations than of any actual remedy. They regarded magic and divination as the highest branches of the profession, and these were exercised solely by the chief priests—the study of disease and its treatment were left to a subordinate grade. Among the Jews, also, the priests were the only practitioners of medicine; but their practice was much more rational, and seems to have been guided by a superior intelligence. They confined their attention almost exclusively to the prevention of contagion, by separating the sick from the healthy, by the strictest attention to cleanliness, using frequent ablutions, and by the use of a few uncertain medicines.

From Egypt the art of medicine was carried to Greece, where it was practised with such success by Esculapius, about 1192 years before the Christian era, that after his death he was raised to the dignity of a god, and temples, in which he was worshipped with divine honours, were raised to his memory in various parts of the kingdom. The priests of these temples were the only practitioners of his art; to them the sick of all classes resorted; and, as the trade was lucrative, it is natural to suppose that they would endeavour to profit by their experience, to enlarge their number of reme-

dies, and to become skilled in their profession. We accordingly find that there was considerable jealousy between the priests of the different temples, that the one tried to rival the other in their number of cures. A stock of knowledge was therefore preserved, and handed down from one set of priests to another; and tablets describing the symptoms and recording the cures were hung up in each temple.

The skill of these priests, founded, as it was, on observation and experience alone, without the least knowledge of the construction of the human body, the nature of disease, or the properties of medicines, must have been very often at fault; and we have good grounds for suspecting, that when at a loss for a remedy, they found that a charm answered their purpose equally well, and took advantage of the superstition and ignorance that prevailed, to work upon the imagination of their patients, and act the part of crafty knaves.

Greece gradually rose in the scale of civilization, philosophy and the arts were cultivated with the greatest ardour and success, and it would have been very improbable that the science of medicine should continue at the low ebb in which we have seen it to exist, or that it should remain in the temples of the priests. Accordingly, between four and five hundred years before the Christian era, a set of men arose who devoted themselves solely to the art of physic, and spread over the country as regular medical practitioners. The most celebrated of these was Hippocrates, who has justly received the designation of the "father of medicine." He was born in Cos, B.C. 460, an island famous as having been the birth-place of the greatest physician, and of Apelles, the greatest painter of that age. The master-mind of Hippocrates rescued the science of medicine from the trammels of superstition, and the delusions of a false philosophy; instead of attributing the origin of diseases to the direct agency of Heaven, he assigned it to natural causes; instead of trusting solely to experience and observation, he taught that, in addition to these, we should endeavour to acquire the knowledge of disease and its cure, by careful experiment, patient investigation, and sound deduction. He ascribed all the phenomena of life and health to a fundamental principle which he denominated "nature,"—a vital principle, which influences all parts of the body, directing and promoting actions which are beneficial, and counteracting those of an opposite tendency. So accurate an observer was he, that many of his descriptions of disease are recognised at the present day as models of correctness and precision. To errors of diet and vitiated air, he ascribed the greater number of diseases. Attention to diet, exercise, and bathing, constituted the chief part of his practice. When these failed, he had recourse to purging, bleeding, diaphoretic and diuretic remedies. He is said to have been the first inventor of bandaging; his treatment of wounds is wonderfully correct; he used the trepan in injuries of the head, and he tapped in hydro-thorax. In his writings we find the first traces of physiological science, and some of his opinions on this subject are wonderfully near the truth.

Up to this period, and long afterwards, anatomy was totally neglected; the dissection of the human body would have been looked upon with infinitely greater horror, than amongst the most illiterate of the present day; all the knowledge, therefore, which physicians in the days of Hippocrates possessed of the human body, was derived from their dissections of inferior animals; they did not even know an artery from a vein, a nerve from a sinew; of the circulation of the blood, and the phenomena of digestion, they had not the most remote conception. How then can we wonder at their frequent and egregious errors in the exercise of their art? As well might we be surprised at getting our watches destroyed by a blacksmith, who knows nothing of their delicate machinery, if we consigned them, when deranged, to his care. Hippocrates taught that the body was composed of four primary elements—fire, air, earth, and water; that these, variously combined, produced the four cardinal humours; and these, in their turn, the different organs of the body. He paid great attention to critical days, on which he fancied that the morbific matter being duly concocted would be evacuated. The works of Hippocrates which have come down to us, have shared the fate of all ancient writings, and are considerably corrupted; several of them have evidently been written at a later period by some of his followers; but enough of them are undoubtedly genuine, to show him to have been the most surprising man of his age.

The followers of Hippocrates, having deviated from the true path in the prosecution of medical science which he pointed out, from their adherence to theory to the exclusion of experience, were called Dogmatists, and for many ages did they reign paramount in the schools of physic.

The next remarkable revolution in the history of medicine happened at Alexandria, about 300 years before the Christian era, during the reigns of the Ptolemys of Egypt—those munificent patrons of literature, who founded the celebrated library of Alexandria, which was said to have contained 700,000 volumes. At this period, Herophilus and Erasistratus first dissected the human body in this city, and made many discoveries in anatomy, which may be called the foundation-stone on which the whole superstructure of medicine is raised. Almost all the parts of the human body which Herophilus discovered and named, retain their anatomical names to this day. Soon after this, however, arose an individual, who is not without a numerous host of followers even at this hour; but whose name no honourable-minded physician would pronounce without indignation. This was Serapion, who may be aptly surnamed "the Quack." He was the founder of a sect called Empirics; his leading dogma was, to admit experience alone as the only source of medical skill, thus running into the opposite extreme from the followers of Hippocrates; he employed remedies for the different symptoms without the slightest reference to the causes of disease. In every science, theory and experience should go hand in hand; idle is the theory that cannot be supported by experience, and our experience would be a confused jumble of facts without sound theory to digest and generalize them. Serapion, also, like all other quacks, availing himself of the superstition and prejudices of his countrymen, the Egyptians, who had the utmost aversion and horror at touching a dead body, discarded anatomy from the list of medical studies, thus flattering the prejudices of his age, and retarding the progress of medical science for the sake of filling his coffers, and earning a short-lived fame.

Having now traced the progress of medical science in Greece and Egypt, let us direct our attention to its introduction into the once illustrious commonwealth of Rome. For more than 500 years after the foundation of their city, the Romans were too much engaged in war to attend to the cultivation of literature and the arts; medicine was therefore only practised in its rude and primitive state. But as they gradually increased in power and opulence, philosophy and the sciences were brought from Greece, and along with them the art of medicine. The first practitioner who acquired any eminence among them was Asclepiades, a native of Bithynia, who, failing as a teacher of rhetoric, without any medical education, commenced to practise physic. His ignorance led him to despise anatomy, and, as a matter of course, to ridicule the practice of his contemporaries and predecessors, declaring that the object of their attendance on their patients was merely to watch the manner of their death, and not to effect a cure. Like all other quacks, he had the cunningness to suit his practice exactly to the manners and taste of the Romans, who by this time were so enervated by luxury, as to dislike whatever gave them pain and uneasiness; and, glad of an opportunity of escaping the strong remedies and rather harsh treatment of the Greek physicians, flocked to a man who proposed to cure, *tuto, celeriter, et jucunde* (safely, quickly, and pleasantly); who followed them in all their inclinations, even permitting the use of wine, in some instances to excess. From these circumstances, and very probably also from the degree of credit which mankind are inclined to give to those who have sufficient assurance to vaunt their own abilities, he gained a very high degree of popularity. There is no doubt but he was a man of great acuteness, and with all his ignorance of his profession he

introduced some improvements; he was the first who divided diseases into acute and chronic, and to have discovered the shower-bath. After Asclepiades we have his pupil Themison, who is celebrated as being the founder of the Methodics; a sect that professed to steer a middle course between the Dogmatists and Empirics. The Methodics became the prevailing sect at Rome, and a great number of distinguished physicians ranked themselves under its banners. This sect was also in its turn divided into three, the most celebrated of which was the Eclectic, professing to adopt whatever was useful from all the sects, and to retain the errors of none. Of this last sect was the elegant Celsus, whose writings have come down to our day, and who was the only Roman citizen who ever became distinguished in physic. From the writings of Celsus, we find that medical science was by this time considerably advanced. The greater part of diseases were distinguished, and names given to them; many had been very carefully described, and the proper treatment in numerous instances adopted; a considerable number of nice and difficult operations in surgery had been performed with success; such as the operation of lithotomy, the operation with the needle for the cure of cataract, the treatment of goitre by extirpation and also by caustic, tapping in dropsy, the use of the catheter in retention of urine, and manual delivery in midwifery after the death of the fœtus. He also gives us a treatise on fractures and dislocations. The knowledge of the structure of the human body, his directions as to diet, regimen, exercise, bathing, and the use of medicines, must surprise those who are apt to look back with contempt on the ignorance of the ancients as to their skill in the healing art.

After Celsus we have no other physician of note till the time of the celebrated Galen, whose name constitutes one of the most remarkable eras in the history of medicine. Hitherto the art of physic had been sometimes retrograding, at other times advancing; but, upon the whole, every succeeding century saw it in a greater state of perfection than the preceding. In Galen, however, was found the limit of that perfection which medical science was destined to attain for a subsequent period of 1400 years. Galen was born at Perganum, a city of Asia, A.D. 131, of wealthy parents, and enjoyed all the advantages of a liberal education. These advantages he turned to the best possible account, and, by diligence and perseverance, he became acquainted with every kind of literature. He was early instructed in the doctrines of Aristotle and Plato, which gave such a bias to his youthful mind, that, in after life, his opinions and theories in medicine were based upon the principles of these doctrines. He studied medicine in the most celebrated schools in various parts of the world, and applied himself to every branch of the profession with the utmost ardour; of anatomy, in particular, he was as perfect a master as his opportunities permitted. Thus prepared to practise his art, he settled in Rome at the age of thirty-four, where his success soon made him an object of envy and jealousy to all the Roman physicians; to such a height, indeed, was this carried, that he was ultimately compelled to leave that city and return to his own country. During his residence at Rome, he was much resorted to by philosophers and men of rank; even the Emperor Marcus Aurelius was attracted by his fame, and, at the invitation of this illustrious prince and philosopher, he again returned to Rome, and soon rose superior to every rival. He gained the confidence and favour of the Empress Faustina, and, as a matter of course, that of all the ladies about court—a circumstance alone sufficient to raise the reputation of a physician far less deserving than Galen, to the highest pitch of fame.

From the days of Hippocrates downwards, physicians had all ranked themselves under some one of the many sects that prevailed. Galen, however, from the superiority of his education, his strength and originality of mind, saw the errors of all the sects, and exposed them with such effect, that after his time they never obtained any credit. In his medical researches he gave himself up entirely to the guidance of nature and Hippocrates; he gave to every kind of remedy a fair trial, and adopted the most efficacious; he availed himself of every improvement which experience afforded, and studied remedies without becoming empirical. In this manner he put the practice of medicine upon the best possible footing. At the same time it must be admitted, that his theories were too limited for the length to which he extended their application; and we must also allow that his system was more theoretical than practical. Galen was fond of writing, and composed a great many books, leaving no department of medical science without bearing evident marks of his industry and genius, and giving a more complete and comprehensive system than had ever before appeared. There are still in existence 137 treatises said to have been written by him, and of these 82 are undoubtedly genuine.

We would naturally suppose that the science of medicine, having received such an impulse from the genius of Galen, would have gone on progressing; but this was not the case. Galen lived at a period when the Roman Empire had passed the meridian of its splendour. In such circumstances, when a system of science is once thoroughly established, and obtains a very high degree of credit, so as to gain a complete ascendancy over every other, the progress of that science is arrested. The great majority of physicians are always servile imitators, from its being so much easier to follow than to lead. An original mind may now and then arise, who can see the errors of the system he has been taught, and who has the ability to correct these errors; but such a person is generally too timid and modest to attack an established system; or if he attempt to do so, he is soon borne down by the hostility and envy of his professional brethren. The system of Galen was, therefore, secured and perpetuated in the schools of physic for many centuries. Physicians of some note appeared, it is true, but their systems were all based upon his model, and the greater part of their writings were merely commentaries on some of his various works.

It was not the science of medicine alone that suffered after the days of Galen; for in the end of the 5th century after the Christian era, the Goths, Vandals, and other barbarous hordes from the north, overran Italy, destroying every vestige of literature and art in the western parts of Europe. Driven from a country which had for a long time afforded them only a feeble protection, the arts and sciences took refuge in Constantinople, the capital of the Eastern Empire. This city maintained its position as capital of the east for many centuries, after Rome, the capital of the west, fell into the hands of the barbarians; it even asserted its independence after being stripped of all its provinces; and it was not till A.D. 1453, that it was captured by the Turks under Mohammed II. During the whole of this period, literature subsisted at Constantinople, but in such a sickly and languishing state, that no advancement was made in any department of science. Galen's system of physic was exclusively followed in the schools, and instead of being improved became gradually deteriorated.

In the 7th century, a new religion and a new empire arose in Arabia. In the year 622, Mohammed proclaimed that there was no god but Allah, and no prophet but himself. He propagated his doctrines by fire and sword, and soon brought all the tribes of Arabia, and the inhabitants of Syria and Palestine, under his subjection. The empire of Mohammed arose among the rude, illiterate, and wandering tribes of Arabia; superstition was its origin, and a blind adherence to the doctrines of their prophet the means of its extension. In these circumstances, the cultivation of literature would be the last thing thought of. We even find that it was a maxim of some of the followers of the prophet, that books which are in accordance with the Koran are useless, and need not be preserved; and if they disagree with its doctrines, they are dangerous, and ought to be destroyed. Fortunately, however, for the world of letters, the Saracens (the name given to these eastern warriors) became at length a mighty nation, and several of their monarchs threw aside the arts of war, and cultivated those of peace and civilization. In this manner was that holy spark of literature preserved, which was afterwards destined to burst forth into a

flame to enlighten the whole of Europe. The capture of Alexandria by the Saracens, towards the middle of the 7th century, gave them an opportunity of studying the books, and becoming acquainted with the literature of the Europeans. They translated many of the Greek authors into Arabic, and thus laid a foundation for prosecuting the study of the various arts and sciences. By chance they were led to adopt the philosophy of Aristotle, and, as a matter of course, the medical system of Galen, which was founded on that philosophy.

Under the dominion of the Saracens, numerous schools of physic were established, and they produced many writers of various degrees of celebrity. About the end of the 8th century, a college was founded in Bagdad, public hospitals were built for the benefit of students, medical science was zealously cultivated, and most of the works of the Grecian physicians and philosophers were translated into the Arabian language. Rhazes, Avicenna, and Albucasis, seem to have been the most celebrated writers on physic of whom the Saracens can boast. These authors, indeed, obtained such repute in Europe, that their works served as text-books for the professors in all the universities for many centuries; the doctrines of Avicenna maintained their ascendancy amongst the European physicians till after the revival of literature. The Arabians, however, added little to medical literature by their own experience and observation. They were the casual inventors of chemistry, it is true; but almost all their knowledge of the healing art was derived from the Greek and Roman authors; they were only useful to medical science indirectly, from their being the means of disseminating a knowledge of the art over Europe. About the middle of the 8th century, the Saracens, having extended their conquest to the west of Africa, from thence came over to Spain, and acquired possession of that kingdom. There they established schools, and inculcated a taste for the various branches of learning; thus repairing the injury to science in the west, which was inflicted by their predecessors in the east, and laying the foundation of that revival of literature in Europe, which now sheds its benign influence over every region of the habitable globe.

Before the arrival of the Saracens in Spain, the only remains of literature in Europe were preserved by the professors of Christianity, and were confined chiefly to the cloisters of the monks; but the surrounding darkness was so intense, and so slight could their influence have been upon the brave but unconverted and most illiterate barbarians of the north, who poured down in hordes over the Roman Empire, that the wonder ought not to be, that they allowed the world to continue so long in darkness and ignorance, but that they were not swept away with the mighty current of paganism and barbarity, and along with them all they possessed of the religious and scientific learning of the age. Amid the war of religious discord, the minds of men get so warped with the narrow views of their sect, that they can only see the virtues of their opponents through a distorted medium, darkened by the mists of prejudice. It is too much the cant of the present day to assert, without the slightest investigation, that the professors of religion in those days were a set of men whose sole aim and interest was to retard the diffusion of knowledge, to place a check upon the progress of civilization, so as to enable them to retain that wicked and selfish hold which they possessed over the minds of men. But what a length of time, may we ask, does it require to civilize the barbarian, or Christianize the heathen million? What progress has Christianity or civilization made among the natives of Africa, Asia, and America, during the last three centuries? And what stupendous efforts have been made, under the most favourable circumstances, by the various denominations of Christians? Let us reflect on these things, and let us impartially investigate the history of the period, and we will find the professors of religion—not all good men, for that will never be—but the great majority, making noble efforts, not only to preserve what they possess of the arts and sciences, but taking every means, under the greatest disadvantages, to disseminate learning over the different provinces of Europe: they established centres of instruction in literature in various places, assembling together the most illustrious talents and learning, and diffusing rays of light in all directions. It is a curious fact, that it is to the period which is known by the name of the "Dark Ages," that we owe the foundation of most of the universities of Europe. The great medical school of Salernum was founded in the 9th century by a monastery of Benedictine monks; and it rose to such distinction, that by the middle of the 10th it was resorted to by invalids of every rank from all parts of the world. The emperors of the period endowed it with many privileges—amongst others, that of granting medical degrees, the examination for which was conducted with the greatest strictness; candidates were required to be examined in various Greek and Arabic authors, to have studied seven years, and to take an oath to obey the rules of the college, to refuse all fees for attendance on the poor, and not enter into any compact with a druggist or apothecary. The druggists and apothecaries were also compelled not only to compound their medicines faithfully according to the prescriptions of the physicians, but also to sell their drugs at a price regulated by competent authority, and not according to their own caprice. The University of Oxford was founded in the end of the 9th century; the Universities of Bologna in Italy, and Montpelier in France, attained great celebrity early in the 12th; in the course of this century, also, the University of Paris was founded; that of Salamanca in 1200; that of Cambridge in 1280; that of Prague in Bohemia in 1358; that of Vienna in 1365; that of Ingolstadt in Germany in 1372; that of Leipsic in 1408; that of St. Andrew's in Scotland in 1412; that of Louvain in Belgium in 1425; that of Glasgow in 1450; that of Aberdeen in 1494; that of Basle in Switzerland in 1469. These, and many others, were granted various privileges, and had the highest honours and distinctions bestowed upon them by the head of the Christian church of the day, who patronised the learned with the greatest liberality, supplied them with abundant resources, and incurred enormous expense in purchasing the best manuscripts for their perusal. In all these universities, the faculties of philosophy (or arts), theology, law (civil and canon), and medicine, were more or less fully developed. Medical science, however, could not have made great advances towards perfection, as long as the professors took the works of the Arabian writers, Rhazes and Avicenna, as text-books for their lectures, which they did up to the middle of the 15th century.

We are told by an eloquent and impartial writer of the present day,* that the origin and progress of civilization depends upon—1st, The intelligence; 2d, The moral principle (based on religious faith); 3d, The facility of communication; and, 4th, The amount of wealth possessed by the individuals composing a given community. Civilization must therefore be retarded, or decline, according to the deficiency of one or more of these requisites. Keeping this in mind, we can easily account for the decline and fall of the empires of ancient Egypt, Greece, and Rome; we can easily account for the slight progress which science and civilization made during the "middle ages;" we can also easily account for the revival of literature in the 15th century. During the middle ages, war was almost the sole occupation of the inhabitants of Europe; the different governments were so unsettled as to leave little leisure for the cultivation of literature, or the acquisition of wealth; the great body of the people were semi-barbarian; commerce was at a stand, and facility of communication was entirely wanting. With this deficiency in the requisites of civilization, is it any wonder that its progress was slow? Is it any wonder that the knowledge of physic should have stood still? Can we wonder that the arts and sciences should not have burst the barriers of ignorance, by which the great body of the people were hedged round?

In 1453 the Turks took possession of Constantinople, and drove the unfortunate Greeks that remained there to seek

* History of Civilization, by W. A. Mackinnon, Esq., M.P.

refuge in Italy, and they carried with them their literary remains. This circumstance contributed greatly to restore and diffuse a knowledge of Greek literature in Italy, and by degrees to spread it to other parts of Europe. Soon after this the Greek language was taught in most of the universities, giving men an acquaintance with the writings of their celebrated philosophers and poets, and contributing in the highest degree to improve the national taste. Other circumstances occurred to favour this progress of learning; the invention of the art of printing, the different governments of Europe having become more settled and tranquil, the di covery of America by Columbus, and the accomplishment of the passage to India by the Cape of Good Hope, giving a spur to commercial industry and enterprise; all contributed powerfully to forward the progress of learning, and the various arts and sciences. The 16th century, therefore, opened with many of the requisites for civilization which had hitherto been unknown; everything was favourable to the advance of literature, and its study was accordingly pursued with great vigour. Early in this century the Greek physic was diligently studied, and the greatest pains were bestowed in illustrating the Greek writers. The Arabian writers by degrees came to be entirely neglected, although the system of physic in both was fundamentally that of Galen. It indeed spoke very ill for the advancement of the science, that his system had now reigned paramount in the schools for 1400 years, and it was a lucky incident that occurred to break the chains which bound men's minds so exclusively to the system.

The art of chemistry appeared first among the Arabians, and was applied by them to the preparation of medicines. Some knowledge of it was communicated by the Arabians to their disciples in Europe, and spread there with their physic. We find, however, little mention of chemical remedies in the medical writings of the 13th, 14th, or 15th centuries; very probably from the fact, that their operation was unknown, that they were prescribed empirically and at random, and that their effects were much more violent than the mild remedies which the Galenists employed. Considerable attention, however, must have been paid to the art by some bold empirical practitioners; for, about the end of the 15th century, a chemical writing appeared, under the feigned name of Basil Valentine, said to have been the production of several authors, but whose names are still unknown. From this work, it appears that chemical pharmacy had been privately cultivated, and was then pretty much advanced. The venereal disease appeared about this period, and completely baffled the skill of the Galenists to cure; it was soon, however, found to give way to the use of mercury, one of the chemical remedies. Many other diseases also, in which the inert medicines of the Galenists proved useless, readily yielded to chemical preparations; thus shaking the public confidence in the perfection and efficacy of the established system. The noted Paracelsus appeared about this time, whose boldness, ignorance, and impudence, took advantage of this state of things, to overturn the medical system of Galen, and raise a chemical system, in direct opposition to it, on its ruins. His vanity and presumption soon gained him great fame, and raised him to be professor of medicine at Basle, when, at his first lecture, he publicly burned the works of Galen and Ovicenna, proclaiming that they were entirely superseded by his discoveries. Although his doctrines were the most extravagant and visionary, he succeeded in founding a sect which shared the public favour with the Galenists, till the middle of the 17th century. Thus was the science of medicine practised by two sects—the Galenists, who adhered as closely as possible to the doctrines of their master, labouring to reconcile every phenomenon to his tenets; their practice was often very complicated, and their medicines were chiefly taken from the vegetable kingdom; and the chemists, whose system was grounded upon attachment to particular remedies, which they fancied had extraordinary power and efficacy; the study and discernment of diseases they entirely neglected; medicines were employed at random, and if a remedy was found useful for one disease, and in one particular constitution, it was set down as a universal cure. The followers of Paracelsus were, therefore, pure empirics; and, unfortunately, it seems to be that which is adopted by the non-professional part of mankind at the present day. The chemical system began by degrees, however, to assume a more scientific form, and continued to rise in public estimation; while the doctrines of the Galenists came to be proportionally neglected.

Towards the middle of the 16th century, the study of anatomy was revived by Vesalius at Pisa. Eustachius followed in his footsteps, and their discoveries tended much to shake the authority of Galen and the ancients in this department. Galileo and Bacon also introduced a new method of philosophising, if not a new system of philosophy, which had the effect of overturning the system of Aristotle, and of loosening that hold which it had so long maintained in the schools; so that, by the middle of the 17th century, the authority of Aristotle in philosophy, and of Galen in physic, were all but completely destroyed.

Every department of the science had now undergone a thorough revision; anatomy had been gradually improving for the space of 100 years, the minds of men were prepared for receiving new facts, when our immortal countryman, Harvey, about the year 1628, discovered and promulgated his grand doctrine of the circulation of the blood; overturning all the former theories of the constitution of the body, and placing the science of medicine on the sound basis of mathematical demonstration. Already had the lacteals been discovered by Asselius, the receptacle of the chyle and the thoracic duct by Pequet. The true course of the blood and the chyle being thus known, the liver was removed from the important function it had held so long in the system of Galen. In this manner, the animal economy, which had hitherto been viewed in separate parts, was studied as a connected whole, and the science of physic placed on a foundation that all the waves of theory will never be able to shake.

Before this period, the Galenists, and still more the chemists, had been accustomed to look upon the state and condition of the *fluids* of the body, both as the sole cause of disease, and the only means of explaining the operation of medicines. They were, therefore, called *Humorists*. But after Harvey's discovery, the attention of physicians was, in some measure, forced towards the *organic* system. The study of mathematics, also, prevailed at the same time, and what were called the mathematical or mechanical physicians arose. By degrees all the systems became blended together, and the science of medicine was gradually improved.

Our celebrated countryman, Sydenham, who has been styled the English Hippocrates, free from the attachments and prejudices of any sect, and studying the writings of all, proposed, about the middle of the 17th century, by his own observation alone, to form a system for himself; he sought rather for theory to unite his observations under general heads, than for facts to confirm his theory. In this manner he gave a model for the prosecution of the study of the art of physic, which has been followed by every sound practitioner since his time. His works still continue to be a standard authority; and, what is extremely rare, they are as much esteemed now as when they first appeared.

Among the most distinguished names in medicine during the 17th century may be mentioned—Glisson, Bartholin, Rudbeck, Fabricius, Hooke, Sylvius, Willis, Riolanus, Fallopius, Bellini, Pitcairn, Mead, and Freind. Towards the conclusion of this century and the beginning of the 18th, we have the celebrated Stahl, Hoffmann, and Boerhaave, each of whom formed a new and considerably different system of physic. After these, in the 18th century, we have the names of Haller, Heberden, Cullen, Brown, and Gregory, all of essential service in bringing the science of medicine to the state of perfection in which we find it. Since the time of these distinguished men, we have many names well known to the student of medicine; but as the art of healing from thenceforward ceased to be theoretical, gradually assuming the character of a science of simple observation, and the

patient investigation of facts, they would not be interesting to the general reader.

We have now traced the history of medicine from the time when it was lost in the depths of an unrecorded antiquity—when we have barely sufficient evidence of its existence to form the ground of a plausible conjecture, down to the present day, when it has arrived at comparative perfection—when the study of pathology, of chemistry, the microscope, and all the allied sciences, can be brought to elucidate its darkest paths, and its most intricate windings; and when, in short, it is capable of conferring the most incalculable benefits on suffering humanity.

## MINERALOGY.

### CHAPTER II.

Amongst the Aluminites are usually placed many of those minerals which have been sent up to the surface of the earth in a melted state by the action of subterranean fire. As might be expected the composition of these minerals varies with the localities where they are found, but there is always a good deal of alumina detected on analysis. Some varieties are porous, others are massive, others are thickly interspersed with crystals of augite, mica, leuzite, &c. *Basalt* is a species of lava generally found in a columnar shape. It is of a greyish black, or brown colour, and opaque. It is found in many parts of the globe. The architectural formality of its structure on a great scale is in striking contrast to the usual irregularities of the external appearance of nature. The Giant's Causeway and Fingal's Cave are fine examples of columnar basalt. *Pumice* is a porous lava of a light grey colour which swims in water. It is found in large quantities at the Lipari Islands. *Clinkstone* occurs massive of a greenish colour; it is to be met with in Scotland, particularly the Isle of Mull and in some mountainous districts of the Continent. Its name originates from the clear tone it gives out when struck. *Pitchstone,* though not a lava, is found in many volcanic districts in company with lava. It has a slaty structure and a vitreous appearance. Its colours are black, brown, grey, and red.

We now turn to the third class, *Calcia,* and the minerals in which it is a principal ingredient.

*Calcia,* or *Lime,* is never found pure, but combined with acids and other earths; it is very extensively diffused over the globe. When artificial means are used to obtain it pure, it is found to be of a white colour, opaque, and without smell, having a strong acrid taste, infusible except by the strongest heat of the oxyhydrogen blow-pipe. It has a specific gravity of 2·3. When exposed to the air it quickly imbibes water and carbonic acid gas from the atmosphere, and falls to powder. It has a strong affinity for carbonic acid, forming carbonate of lime.

*Chalk* is a carbonate of lime. It is found in vast deposits, generally including nodules of flint. It is of a white colour, has an earthy fracture, adheres to the tongue, and is perfectly opaque. It is extensively used in various manufactures. When burnt it forms an inferior kind of lime. An immense quantity of fossilised organic remains is embedded in the chalk group.

*Limestone* occurs in great variety, both as regards colour and compactness. Some kinds are beautifully veined, and hard enough to be worked into a fine marble. The statuary marble of Carrara is a limestone. It is a very useful stone for building purposes, being durable and of a neat appearance when hewn. It makes an excellent lime when burnt. The deposits of limestone in Great Britain are large. The crystallised variety is called

*Calcareous Spar,* which occurs in an extraordinary number of forms, upwards of 700 having been enumerated. The primary form is a rhombohedron. Hardness 3. When pure it is colourless, but it frequently occurs tinted with various colours by the admixture of other minerals. Its lustre is vitreous. When transparent, as it usually is, it possesses the remarkable quality of double refraction, and hence it is often called double refracting spar. Some fine specimens are brought from Iceland. Dog's Tooth Spar is a variety frequently found in Derbyshire.

*Oolite,* a species of sandstone found in compacted grains like little eggs, whence its name. It occurs in large beds in many parts of England, and is a good deal used as a building stone. Its appearance is very neat, but it is soft and not durable. Bath stone is an oolite.

*Satin Spar* takes a fine polish. It is white or grey in colour, and marked with black streaks; this, with a satin-like lustre, gives the stone its name. It is found, amongst other places, at Alston Moor in Cumberland.

*Agaric Mineral* is a beautiful mineral of great variety. It is of a pure white colour, and is light enough to float like flour on the surface of water. It is found in the crevices of rocks both here and on the Continent.

*Peastone,* or *Pisolite,* is found in compacted lumps of the shape and size of peas. It is usually white, soft, and bitter. It is not common.

*Stalactite* and *Stalagmite* are names applied to those deposits of carbonate of lime found in caverns and similar places. When water, strongly impregnated with lime, drains through the roof of a cave, long ropes and wreaths of matter are left as it evaporates, clinging to the waters or depending from the ceiling. These are stalactites. As the water drips down to the floor a deposit gradually rises, and this is called stalagmite. Water thus charged may also be induced to deposit the lime upon substances for which it has an affinity, and thus, what is vulgarly termed a petrifaction is formed; but the fact is, that there is but one external coating of earth placed upon the substance. Some natural springs of water are so satured with the lime that a deposit is readily laid upon anything—thus a bunch of grapes, and a twig with leaves, have been "petrified" by them in a short space of time.

*Dolomite,* called after its first observer Dolomien, occurs massive, grey or yellowish in colour; sometimes it has a slaty structure. It is a good deal softer than limestone, and sometimes it will allow the nail to make an impression. It contains about 59 per cent. of carbonate of lime, and 40 per cent. of magnesia. The Appenines are almost wholly formed of dolomite. There are several thicknesses of magnesian limestone, a species of dolomite, in the north of England.

*Bitter Spar* is the name given to the crystallised varieties of dolomite. In colour is greyish or yellowish white, but it is often coloured brown, yellow, green, and pink, by metallic oxides. Hardness from 3 to 4. It is with difficulty distinguishable from calcareous spar and talc-spar, the crystals being of a very similar shape.

*Pearl Spar* occurs massive and crystallised in obtuse rhomboids of a white or yellow colour, and with a pearly lustre. It is found in Derbyshire and Cornwall.

*Arragonite,* so named from its having been abundantly found in Arragon, is a mineral composed of from 95 to 99 per cent. of carbonate of lime, with a little strontian. It is met with both massive and crystallised. The primitive crystal is a right rhombic prism. Hardness from 3 to 4; specific gravity 2·9. Some varieties are very beautiful. One variety, called *flos ferri,* consists of numerous fibrous crystals, radiating from a centre with a satin-like lustre. Occasionally it is seen in a stalactitic shape, hanging from a roof or poured out on the ground. In the Soane Museum, London, there is a remarkable specimen of Arragonite

in the shape of a sarcophagus covered with Egyptian hieroglyphics. It is nine feet four inches long, and three feet eight inches wide at the widest part. It is cut out of a single piece of stone. It was brought by Belzoni, the celebrated traveller, from the pyramids, and purchased of him for £2000. The rays of a candle penetrate through it where the stone is three inches thick.

*Apatite* occurs only crystallised in the usual form, being a regular six-sided prism. Hardness between felspar and fluorspar, specific gravity from 3·25 to 3·5. Usually translucent, its colours being white, yellow, blue, and green. Occurs amongst two primitive rocks. It is met with in Cornwall. It contains upwards of 40 per cent. of fluor phosphoric acid.

*Fluor Spar* is a combination of lime and fluoric acid. Occurs massive and crystallised, the primary form of the crystal being a cube, but the secondary forms are very numerous. It is met with colourless, and in many varieties of hue, purple, green and blue, being the commonest. Lustre vitreous; hardness 4; specific gravity 3·14; fracture conchoidal. This mineral, under the name of Derbyshire spar, is worked into pieces of ornament, such as vases and candlesticks.

*Gypsum* is a sulphate of lime, but occurs compact, fibrous, and earthy, of a red or white colour. It is translucent on the edges. The earthy variety, after the water has been expelled, is called Plaster of Paris. There is a great mass of it at Montmantre, near that city.

*Selenite* is the crystallised form of gypsum. It is found amongst the clays. The usual shape is an oblique parallelopiped.

*Antrydrite* is also a sulphate of lime occurring massive, crystallised, granular, and fibrous. It is principally found in the mountains of Austria.

*Datholite*, a mineral composing lime of silica and boracic acid. It is not a very common mineral. It is slightly translucent, of a greenish or greyish colour, and occurs both massive and crystallised.

*Boracite*, a mineral composed of lime, silica, magnesia, and boracic acid. It is met with of a white or green colour, in Brunswick and Holstein.

*Magnesia* is a fourth of the eleven earths we mentioned in our first chapter. When pure it is without colour, taste, or smell; it is almost insoluble in water. It attracts carbonic acid from the air, and forms the salt usually known as magnesia, which is in fact a carbonate of magnesia. It has a specific gravity of 2·5.

*Magnesite* is a mineral of a greenish white colour, capable of being slit into thin sheets. It is a hydrate of magnesia that is a compound of water and earth,—the former ingredient being about 30 per cent. It is generally found in serpentine rocks.

*Meerschaum* (literally *sea foam*) is a massive soft mineral used in the manufacture of pipes and porcelain. It is found in many places, but that most prized is procured in Turkey.

*Pleonaste* or *Ceylonite* occurs granular and crystallised. It was first found in Ceylon, whence one of its names. It is of a dark green colour.

*Iolite* occurs massive, disseminated and sometimes crystallised. It has a dark blue colour. Some of the finest specimens have been brought from Greenland.

*Chrysolite*, a mineral occurring both massive and crystallised, which contains a good deal of oxide of iron in addition to magnesia and silica. The primary form of the crystal is a right rhombic prism. Lustre vitreous; colour green, yellow or brown. Specific gravity 3·3. Hardness from 6 to 7. It is translucent and sometimes transparent. It is used as a personal ornament.

*Olivine* is a variety of chrysolite. It is found in basalt in Hungary and Bohemia. It is of an olive-green colour.

*Serpentine* is a mineral of a green colour, the origin of which has puzzled the geologists. The beds are of a considerable size. It takes a fine polish and is much prized as a marble; specific gravity 2·56. The kind called precious, is harder and takes a finer polish. Serpentine is met with in Cornwall and Scotland.

*Stealite* or *Soapstone* occurs both massive and crystallised. It has a soft greasy feel, and a greenish or yellowish-white colour, translucent on the edges. It is infusible before the blowpipe. It is found in Cornwall and in Scotland; specific gravity 2·6. Its constituents are silica, magnesia, alumina, and a little oxide of iron. A spotted variety is wrought by the Chinese into small figures and other ornaments. French chalk is made from stealite.

*Chlorite* (from a Greek word signifying *green*) is usually found diffused through other minerals to which it imparts a green tinge. Thus the green spots sometimes seen in writing slates are owing to this mineral. It is found in the Alps, in Dauphiné, and in Scotland. Before the blowpipe it leaves a black porous cinder behind; specific gravity 2·6. A little iron is found in some of the varieties.—We now pass to the minerals which contain the earth named Zirconia; and these are the *Zircon, Jargoon,* and *Hyacinth.*

All of these minerals occur in a crystallised form only, and their composition is pretty nearly alike. Their primitive form is an obtuse octahedron. Colour grey, passing by various shades into red; sometimes but rarely white and green. The earth zirconia in the gem called zircon is nearly 70 per cent. with a trifling admixture of oxide of iron. In the hyacinth the iron is about 2 per cent. Specific gravity 4·5; the crystals have a slight power o double refraction. They are infusible before the blowpipe, but heat dissipates their colour. They are found in many parts of the old and new world.

The earth *Glucina*, in its pure state, is a light white powder tasteless and inodorous, insoluble in water and infusible; specific gravity 3. It exists in a very small proportion on the earth, in fact it has only been detected in the three stones *emerald, euclase,* and *beryll.*

The emerald and beryll differ very little in appearance or composition. They usually occur in hexagonal prisms, with a vitreous lustre, and a conchoidal fracture. Hardness from 7 to 8; specific gravity 2·6. Silica is found to the extent of 66 or 68 per cent., whilst glucina varies from 12 to 15 per cent. They contain a good deal of alumina and several metallic oxides. The term emerald is applied solely to those varieties which are coloured green, and beryll comprehends all the others. The finest emeralds are brought from South America, and some have been found in Egypt. Beryll is principally found in Brazil and Siberia; in the latter place there are mines excavated in procuring it. It occurs also in France, Bavaria, Bohemia, and Ireland. A piece of extraordinary size was discovered a few years ago in New Hampshire, United States. It was four feet long and weighed 238 lbs. Unless a flux is applied to it, heat acts upon it with great difficulty but with borax a clear glass is produced.

*Euclase* is a blue or colourless mineral occurring in crystals, the primary form of which is an oblique rhombic prism. It has a vitreous lustre with a hardness of 7, and a specific gravity of 3. It has the power of double refraction. It has been found in Brazil and Peru. Glucina forms a large proportion, as 21 per cent. Silica and alumina with oxides of iron and tin are the other constituents.

The earth *Yttria* has only been discovered in one mineral named *Gadolinite*, which is sometimes red, sometimes black. It is usually massive and but rarely crystallised; specific gravity 4. It is very brittle, and when treated with nitric acid its colour disappears and it forms a jelly-like mass. Yttria is found in it to the extent of 45 per cent. The name of the earth is taken from the place, Ytterby in Roslagen, where Gadolinite is chiefly found.

The earth *Barytes*, (so called from a Greek word signifying *heavy*) is of much more frequent occurrence in nature than the two last earths, but has never been discovered pure. When it is free from other matters it is found to be of a greyish white colour, with a specific gravity of 4, and an acrid taste. It is highly poisonous. It has a strong affinity for water, and when moistened it becomes extremely hot, and if a larger quantity of water is added, it crystallises into a hard mass. Only a high temperature will fuse it.

*Witherite* is a compound of carbonic acid and barytes, named after its discoverer, Dr Withering. When found crystallised its primary form is a right rhombic prism, but the usual form is a six-sided prism. It is generally opaque but sometimes it is colourless and translucent. It is sometimes coloured green and yellow; specific gravity 4·3. The artificial salt, carbonate of barytes, is soluble in water with great difficulty. At the boiling point it requires 2300 times its own weight to effect a solution.

*Sulphate of Barytes* occurs both massive and crystallised in large quantities in the lead mines of the north of England. The primary form of the crystal is a right prism. It is usually of a white colour and opaque. It is very heavy, having a specific gravity of 4·7, and hence by the miners it is usually termed Heavy Spar. Barytes forms about 67 per cent., and sulphuric acid the remainder. A fibrous variety is called Bolognian Stone.

The earth *Strontia* is of a greyish white colour. Specific gravity between 3 and 4. It has an acid taste; it is fusible with difficulty. It is named from the place it came from when it was first found.

*Strontianite*, being a carbonate of this earth, is found both massive and crystallised, and the primary form of the crystal is a right rhombic prism. Its colours are brown, grey, green, and white It is transparent and translucent, with a vitreous lustre. Hardness between fluor spar and carbonate of lime. Specific gravity 3·6. When fused by the blow-pipe it gives out a purple light.

*Celestine* is a sulphate of strontian, occurring both massive and crystallised. Primary form a right rhombic prism. It is brittle with a hardness of the same degree as the last mineral. Its colour is white, tinged with blue and red. Specific gravity 3.8. Before the blow-pipe it fuses into a white enamel. It is found near Bristol, in France, Sicily, &c.

*Stromnite*, named from Stromness, in Orkney, where it has been found; is a compound of strontia, barytes, and lime, with acids. Lustre pearly, structure fibrous, soft, and brittle, but not fusible by the blow-pipe. Specific gravity 3.7.

*Grunerite*, a massive mineral found in Hanover, is a compound of the sulphate of strontian and barytes. Colour white. tinged with blue. Specific gravity 3·7.

There yet remain a few minerals to be described, which, from their anomalous structure, we have been unable to classify in the foregoing list.

*Alum* is found as an efflorescence on some kinds of clay and slate, and it sometimes occurs in a stalactitic shape amongst slate rocks. When freed from impurities, dissolved in water and recrystallised, it forms the alum of commerce. It is a composition, of the sulphate of alum and potash.

*Native Saltpetre* is found as a crust upon the water.

*Natron*, in some places, effloresces through the ground in regular crops. It has a saline taste, and is of a whitish colour. It is also found in some mineral springs, and in some lakes in Egypt and Hungary.

*Common Salt* is a muriate of soda, found in large beds beneath the surface of the earth; and springs, and large sheets of water are found impregnated with it. It is crystallised in the form of a cube. The salt mines of Cheshire and Switzerland are extraordinary places which every traveller to those parts has seen. Salt is found in them in a pure state perfectly transparent.

*Sal-Ammoniac* is a muriate of ammonia. It is chiefly found in crusts, having a green or brown colour. It does not dissolve in water. It is sometimes found crystallised. The strong effluvium it emits is well known.

We have now completed our survey of the Earths, the first and great division of the mineral kingdom, and we shall proceed in our next paper to the class of Metals.

## BODMER'S SLOTTING MACHINE.

The example of Slotting Machines, constructed by Mr. Bodmer, may be considered as one of the best of the species, whether as regards accuracy of workmanship or compactness. The peculiar shape and stiffness of the framing adds materially to the excellence of its performances, and the different minor arrangements contained in it are so adapted as to produce the required end at once, simply and well.

Fig. 1 is a side elevation of the machine, showing the table and adjusting apparatus.

Fig. 2 is a front view, taken at right angles to Fig. 1.

Fig. 3 is a transverse section of the tool-slide and connecting-rod, &c., and

Fig. 4 shows the mode of adjustment of the tool, on a larger scale.

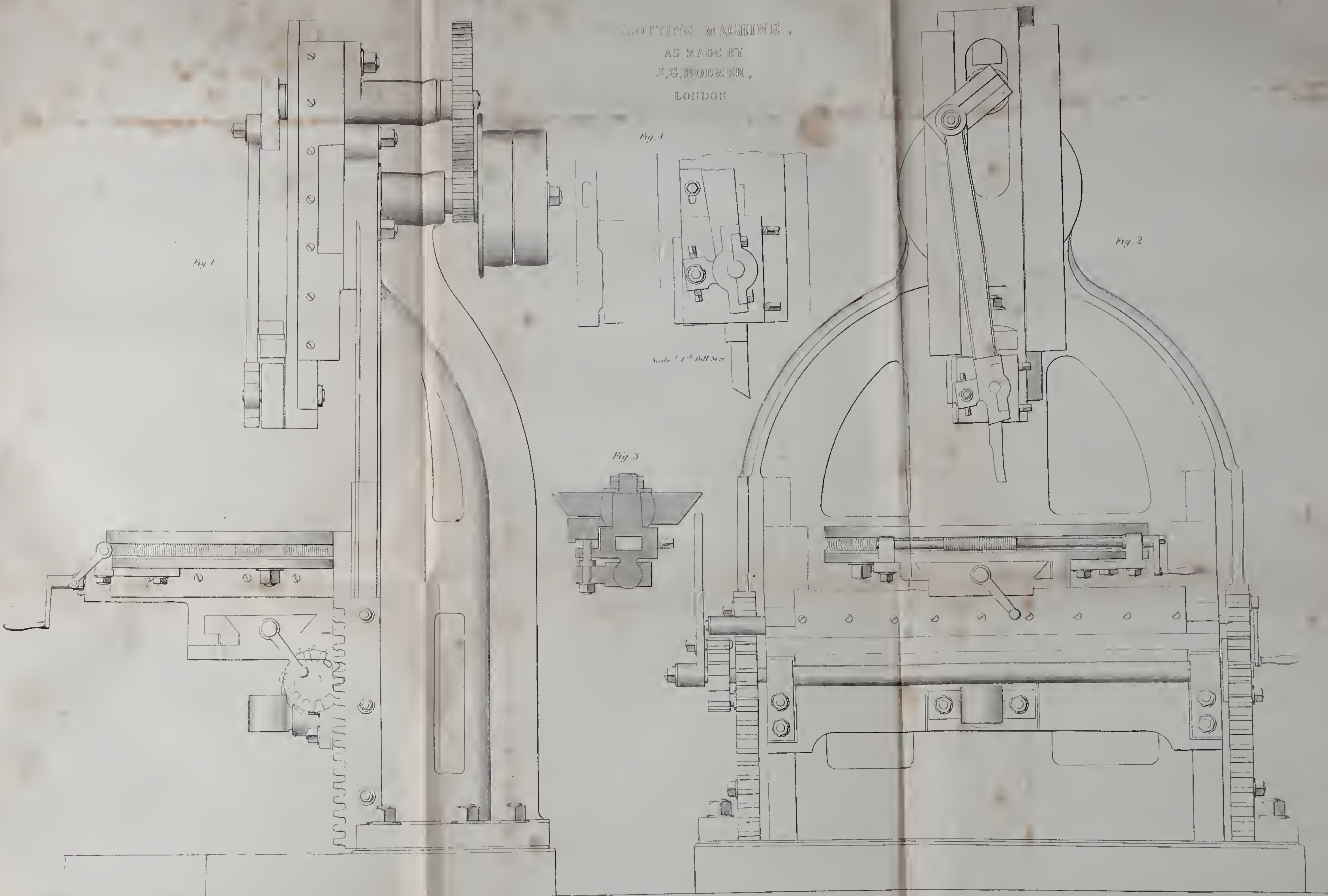
The views are sufficiently large and explicit, as to enable us to dispense with a closely literal description. It will be seen that the frame, which is cast in one piece, is of a curved section, fitting pretty closely to the contour of the table, thus causing stability and strength. A stout eye is cast on the upper end, as a bearing for the fast-and-loose pulley shaft: this shaft carries a pinion gearing with a large spur-wheel keyed on a second overhead shaft, which carries the driving disc. From hence the motion is transmitted in the usual manner by a connecting-rod, jointed to a pin on the tool-slide The circular motion of the table, which is most useful for the rounding of small objects, is obtained by a worm gearing into a set of teeth cut on the periphery of the table. The rectangular motions again are obtained in the usual manner, by two screw shafts working into nuts on the upper and lower slides. The table is also moveable in a vertical direction, by means of a pair of vertical racks screwed to the framing; into these racks, two pinions, on a front horizontal shaft, are arranged to work, being driven by a ratchet lever on one side, so that the table may be raised or lowered to suit any variety of work.

## PROPOSED
## IMPROVEMENT IN THE NOTATION OF MUSIC.

(COMMUNICATED.)

Music in past ages was encumbered with many inconveniences. At first there was no time-table—consequently no correct means of performing pieces in concert, till Guido Aretino illuminated the science with the invention of the time-table, and a new staff containing five lines instead of four. Since his time the art has gradually progressed till it arrived at its present state of *partial perfection*. I say only

## SLOTTING MACHINE,
AS MADE BY
J. G. BODMER,
LONDON




*Scale 1/6th Full Size*

partial, because I do not think it yet perfect either in theory or practice. A little emendation has occurred to me in the course of my musical pursuits illustrative of this statement. I often thought that there was no necessity for a trehle and bass clef, which cause the notes to read differently in each staff; but as there was only the difference of a third between them, that one clef would serve. I proposed some time ago to adopt the following plan, which I here subjoin. Instead of placing the bass clef F on the fourth line, let it be put on the fifth, and then both clefs will read alike: for instance, the note on the first line in each staff will he E, and on the last F; all the difference being that the bass notes are two octaves or a fifteenth below the treble notes. The new hass clef stands thus:—

same as

E F G A B C D E F     E F G A B C D E F

which very much simplifies the art of reading music. If this system were generally adopted, and I see no objection to it, singers or performers could never be perplexed by a mixture of clefs in the music, as the notes would still bear the same name. Organists and pianists would also be much benefited by it, for the learning of the notes and clefs could be accomplished in one-half the time at present occupied in doing so. There is now a great perplexity in music for both hands, written on both staves, inasmuch as the notes do not read alike. If you think it likely to interest the musical part of your readers, perhaps you will kindly insert this in your useful Journal. If it should be thought an innovation upon established practice, and therefore rejected hy the professors, I entertain the hope that some amateurs and singers at least may adopt it, and derive benefit from it. All my object in making it public is to lay it openly before the musical world to have its merits tested. In favour of it I will only add, that no trouble is caused by its introduction; the only difference will be, that composers and transcribers write their hass music in the new clef on the fifth line. There is nothing troublesome or complex about it; its only recommendation is simplicity and utility. It merely tends to simplify the beautiful and divine art of music.—I remain, yours, &c.

H.

## POLITICAL ECONOMY.

### CHAPTER I.

#### LABOUR.

Every hard-working man knows what labour is, but political economists must strain a little to arrive at a definition of it. Without aiming at rigid exactness, we may call it "the application of power to purposes of utility." And assuming that this utilitarian definition is appropriate enough, we may proceed to divide labour into three varieties. The first is that applied to the raising and the appropriation of the produce of the earth: this is agricultural labour. The second is that expended upon the conversion of that produce into articles of use: this is manufacturing labour. And the third is that applied to the distribution of the products of these species of labour among consumers: this is commercial labour. It is this expenditure of power which gives fertility to the earth, confers value upon the mineral treasures contained in its bosom, turns to use the inferior creatures which live and move in the seas and rivers that water it, and saves from waste the spontaneous vegetation which clothes it. All these are without value to the family of man, till they are subdued, gathered and combined by human industry.

There is indeed a fourth species of labour which is of early use for the regulation of the other kinds: this is intellectual labour. It is this labour which builds up science, and reduces the operations of the agriculturist, the manufacturer, and the merchant, to practical arts. Legislators and magistrates, men of science, physicians, teachers, artists, and poets, all exercise functions calculated to increase the comforts, the enjoyments, and the conveniences of social life, and ought therefore to be placed like the husbandman, the manufacturer, and the merchant, upon the list of useful labourers, and entitled with them to a due share of the rewards of labour. Without these, man might exist; but he would exist as a savage, and the withdrawal of the functions of any one—the least important, would be felt as a want in the social state.

As man's comforts augment, his labours multiply; for labour is the first price, the original purchase-money that is paid for all things. Indeed, so omnipotent is this thing *labour*, that political economists have agreed to call it the only source of *wealth* —meaning by wealth, the riches, which, apart from the spontaneous products of the earth, and the unappropriated gifts of nature, possess value in exchange. The creation of exchangeable value is the legitimate aim of labour. It draws upon nature, as the great capitalist which from the beginning of time has furnished the raw material on which industry, since it began its functions, has been exercised; but it has not added a single material particle to the great fund; it has created no material thing; but like the chemist, it separates and combines, and it is the labour expended upon the appropriation and the modification of qualities, which brings a *price*. Whatever requires no labour to appropriate, has no exchangeable value—it cannot be *sold*, however intrinsically valuable the thing may be. No one will pay, for instance, for the light of the sun, or for the air he breathes, because he partakes of them, and has all the advantages which they give, without any man's labour; and it is only when water is conveyed to us from a distance, that it has a price; and it is the price of the labour expended upon the conveyance that we pay to our water-companies. In localities where nature has placed the article within the convenient reach of everybody, it has no exchangeable value. Land, in the same way, acquires a value by appropriation, and indeed all things which are in common and alike the gift of nature to all men, the man who first sets the mark of his industry upon the article, gives it a value which never can be severed from it, and that man is he who has the best and the only right to say—*this is mine*. The child, when it places a chair by the fire, claims that chair for the occasion, upon this principle, and the right is recognised by every other child in the family: the appropriation of the chair, and the labour of placing it, constitute the right.

Some indeed state the subject differently. They tell us that it is not the labour which is expended upon a thing that gives it value; on the contrary, that it is on account of its selling for a high price that labour is expended in procuring the thing. A fisherman, for instance, would get as much for a salmon which should accidentally leap into his boat, as he would for another which had cost him many hours' toil to catch. The case may be put more aptly, by supposing that a hodman finds a sovereign: the piece of money is worth just as much to him as if he had received it as the wages of his labour. This at most is a distinction without a difference. The fisherman values his chance salmon by the average amount of labour which a salmon represents, and the hodman similarly values his sovereign. If salmon and sovereigns could be got by everybody with the same facility, it is plain that their exchangeable value would be estimated at just the labour necessary to collect them. It is true the case is not always so plain. If a workman whose wage is 20*s*. a-week, should, when eating an oyster, meet with a pearl for which a jeweller gives him ten sovereigns, he may not at first see why the pearl which cost him nothing, should be valued by the jeweller at ten weeks of his labour; nor may the jeweller be able exactly to explain. He however gives the price, because he knows that he would pay as much in the regular course of trade, and pearls which come to him, in that way, are valued in exchange by the average labour of procuring them. We might indeed describe pearls as costly because they are scarce; and being scarce, they represent much expended labour.

Labour is the great architect of our enjoyments—it is in fact the creator of them; and it may be laid down as an axiom, that the culture of the mind keeps pace with the culture of the material products which nature spontaneously furnishes. The savage—the hero of J. J. Rousseau, and those who have taken up patches of the mantle of the Genevese philosopher—has few occupations, and he stands like a desolate thing on the verge of

social existence. His slow progress towards civilization is in the steps of industry. At first he is contented to gather the spontaneous fruits which the forest produces, and to pick up the shellfish which are strewed on the shore; but after a time he becomes a hunter, feeds himself with the flesh of the wild animals of the chase, and clothes himself with their skins. As his intellect expands, he perceives that the proceeds of the chase are precarious, and he exchanges the life of a hunter for the more certain one of a herdsman and a shepherd. The transition is marked by amelioration of his condition, his passions are softened down, and his reason cultivated, and he finds it easy to add an unfailing supply of vegetable food to the produce of his flocks: he becomes an agriculturist. He now longs for comforts, variety of diet, better clothing, and more commodious lodging; and in order to procure these, he becomes a manufacturer. Here he enters upon the last stage of improvement, and he wends his way onward by the all-conquering force of industry, acquiring at every additional step new facilities of ministering to his desires, and new capabilities of subduing the powers of nature, and rendering them subservient to his convenience.

As labour is that which confers upon a commodity exchangeable value, society would early perceive the advantage of directing it to various objects. One man might be acknowledged as the best bow-and-arrow-maker of his tribe, but another might use them more dexterously in the chase; a third might be more ready than all others in dressing hides and cutting them into clothing; a fourth might be the most skilful in building huts; while some again were only fitted, either by talent or taste, to be herdsmen and cultivators of the ground. Under these circumstances it would evidently be the interest of all, to establish a division of employments corresponding to the taste and talents of the members of the fraternity, and thus give rise to the practice of barter which is man's peculiar distinction. The armourer would barter his bows and arrows for the surplus venison of the hunter, the hides of the tanner and tailor, the services of the hut-builder to improve his dwelling, and the grain of the agriculturist. All these would barter with all the others in their turn, and thus the necessity of violence and fraud would be superseded. In the civil and military duties, we may suppose a corresponding division. The most daring and reckless in the band would be the leader in war; and the most fluent speaker would be the diplomatist of the tribe. The strong intellect of man, operating by the common faculty of language, may be supposed as transmitting gathered experience and reflection from generation to generation, and, accumulating as it rolled on in the deep current of silent time, would digest the rude processes into systematic operations, and the crude notions of the village oracle into intellectual philosophy.

Whether this was precisely the mode in which diversity of occupations arose, is of no moment: it is enough that it conveys a first notion of the utility of a division of employments. Modern practice exhibits the principle carried perhaps to its utmost extent —in many cases, indeed, to the detriment of the operative. The beneficial effect to society, considered in an economical point of view, is very remarkable; *it saves time, and the work is better done*. The economy of different professions is too obvious to need illustration; the whole experience of social life is one continuous proof, that it is the main distinction between civilization and the lowest depths of barbarism. In the ultimate divisions of labour which are now instituted, the physical effects are of a similar though less obvious nature. By reducing every process of manual labour to the simplest possible operations, less time is requisite to acquire a knowledge of them; and greater dexterity and despatch is attained by constant repetition of the same process. A very short time is required to learn the art of heading a pin or pointing a needle, and an individual soon acquires a despatch in either of these operations, which is reckoned altogether astonishing by those who have been trained to some other occupation at which possibly they are comparatively skilful; but it would require considerable perseverance in any one individual to attain a far inferior degree of dexterity, in performing all the operations necessary to the perfecting of one of these little tools. Dr Adam Smith states, that a boy brought up to the trade will make 2300 nails in a day; while a common smith, although accustomed to handle the hammer, will not be able to make above two or three hundred in the same time, and these, too, very bad ones. But this is a clumsy illustration compared with the dexterity acquired by the little needle *piercer*. This is commonly a child, who, receiving the needles with the ends flattened and properly annealed, pierces the eye by laying the flattened end upon a block of steel, applying to it the pointed end of a small punch and striking the other with a little hammer; the operation is first performed upon one side and then the other. Another child trims the eye by a similar process, except that he uses a block of lead, and drives his punch completely through; then laying it sidewise upon a flat piece of steel, with the punch still through it, he taps it on each side, making the eye take the form of the punch. These two children pierce and trim the eyes of 4000 needles per hour, and if the minuteness and accuracy of their work is not sufficiently obvious on inspecting it in a fine needle, it may be mentioned, that it is common with them to punch one human hair and thread it with another, for the amusement of visitors.

There is another consideration besides dexterity, of equal importance to consumers: it enables masters to apply exactly the amount of skill and strength to each operation, which is necessary to its execution; thus reducing the cost of production to a minimum. This was first explained by Mr Babbage in his *Economy of Machinery and Manufactures;* and he illustrates it very minutely in explaining the operations of pin-making. To make 5546 pins, weighing one pound, the Professor informs us, employs four men, four women, and two children, rather more than seven hours and a half, and the total amount of their wages for the work, each being paid according to skill and time employed, is 1*s*. 1*d*. The daily wages of the persons employed, varies from 4½*d*., the sum paid to the boy who assists in twisting and cutting the heads, to 6*s*., the sum paid to the man who finishes the most difficult part of the art. Of the seven hours and a half consumed, four are taken up by a woman in heading; rather more than two hours by another woman in preparing; and the remaining hour and a half is spent in straightening the wire, pointing and tinning. Without this division of labour, it is obvious that the pin would require for its manufacture a workman equal to the highest paid; that is, one capable of doing the most difficult as well as the easiest part of the process; and this workman would spend more than half his time upon heading—a part of the work which is paid at 1*s*. 3*d*. a-day, while he is paid 6*s*. Pins would therefore be at least four times their present price; and as the single operative could not be expected to attain the same expertness in the minor details, as those whose undivided attention is directed to them, there is every reason to believe, that the pins, besides being four times as dear, would also be four times worse made.

The same remarks apply to every extensive manufacture in the country, and hold equally just in agriculture. Even in intellectual pursuits, the same advantages are felt from adopting gradations of employment. A novelist would make a poor hand at expounding Newton's Principia, and the Pegasus of a mathematician would in all probability be very stiff in the joints. The chemist separates himself from the mechanical philosopher; the physical astronomer from the astronomical observer; and the political economist from the politician. The vocation of the barrister is distinct from that of the conveyancer, the equity draftsman, attorney and solicitor. The medical profession is similarly divided into physicians, surgeons, and apothecaries. It is not indeed advisable that the several practitioners should be entirely ignorant of everything beyond their own immediate calling: this were to curb the mind, and bring down its general powers to the lowest possible point. There is besides no branch of collateral knowledge that has not its use and its bearing upon the main object of pursuit. In what are called the learned professions, it is essentially necessary to absolute success, that the extra proficiency required in any special department be based upon a solid foundation of general knowledge. A surgeon who is ignorant of anatomy and physic would make sad havoc among his patients; and evils of the direst kind would follow in the wake of a physician, who would take upon himself to prescribe without a very extensive knowledge of physiology. The fundamental knowledge of the civil engineer must be both extensive and accurate, if he would hope for success; and there is not a mechanic in the country, whose abilities would be deteriorated by a very wide knowledge of general physics. A knowledge of astronomy and geology would not add to the expertness of the needle-piercer, but neither would it detract from it, and the faculties of the mind might thereby be saved from that degradation which too frequently overtakes those condemned for life to

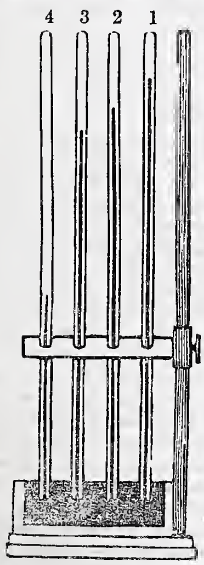
one unaltering occupation. It is the demands of society for the products of industry which has promoted the minute subdivision of labour referred to: it is a positive evil to the individuals employed, but a positive advantage to the community, and will therefore continue to be followed, in all rich and civilized countries, where the standard of excellence in every department of art, science, and scholarship, is placed so high that it can only be reached by keeping the attention steadily directed towards it. To minds so engaged, the acquisition of general knowledge is relaxation to the working faculty; and it tends to elevate the general character. Man is an industrious animal; but it must also be remembered, that he is a social animal, and that his social state has always a marked relation to the qualities of his mind.

## NATURAL PHILOSOPHY AND CHEMISTRY.

### CHAPTER V.—(*Continued.*)

#### ON VAPORIZATION AND VAPOUR.

Vaporization, as already stated, takes place at all temperatures however low; and it is only by the influence of external circumstances that the change is accompanied, at a particular temperature, by the phenomenon of boiling. This fact may be proved by exposing water in a shallow vessel for a few days, when it will gradually diminish, and at last disappear entirely. Most other fluids, if not all, are susceptible of this gradual dissipation; and even ice and snow pass off in the vaporous condition when similarly exposed, at temperatures far below that necessary to their liquefaction. Camphor manifests a very powerful tendency to evaporation at the ordinary temperature of the atmosphere; and arsenic cannot be melted, for a slight elevation of temperature causes it to pass off from the solid to the vaporous condition. "The particles of volatile bodies* appear thus, at all temperatures, to repel each other to a certain degree, and to spread abroad, in the form of vapour, until they occupy completely the space in which the body is contained, and exercise a pressure which is equal to the force of their mutual repulsion." This is termed the *elasticity*, and sometimes the *tension*, of the vapour; and is easily estimated when not greater than the atmospheric pressure, by observing the effect produced upon the column of mercury in a barometer tube. Thus, suppose we prepare four barometers for the purpose, and arrange them in a frame, with their lower ends dipping into a trough of mercury, as shown in the figure. Allowing the first barometer to remain as a standard for comparison, pass a very little water into the third, second, alcohol into the third, and ether into the fourth;† these liquids rise and float upon the surface of the mercury in the tubes, and form vapour, which, occupying the empty space, presses upon the surface of the mercurial column, and counteracts a part of the pressure of the external atmosphere. The space through which the mercury descends in the tube, is the measure of the elasticity of the vapour, the shortened column of mercury showing the difference between the atmospheric pressure without, and the pressure of the vapour within. Thus, supposing the mercury in the standard




barometer to stand at 30 inches, and that the temperature at the time is 80°, the mercury will stand in the tube containing the water at 29 inches, in that with alcohol at 28$\frac{1}{10}$ inches, and in that with ether at 10 inches. The elasticities of these vapours are therefore at the given temperature, and measured in inches of mercury, as follows:—

| | | | | |
|---|---|---|---|---|
| Vapour of water, | 1 inch, | that is | $\frac{1}{30}$ | of the atmospheric pressure. |
| ... of alcohol, | 1$\frac{9}{10}$ inch, | ... | $\frac{1\cdot9}{30}$ | |
| ... of ether, | 20 inches, | ... | $\frac{2}{3}$ | |

The experiment illustrates the different degrees of volatility of the liquids employed; but it may be made further to show that the elasticity of vapour changes with the temperature under which it is produced. Dr Dalton was the first to prove this in a satisfactory manner, and his method of conducting the experiment is very simple. He thus explains it:—"I take a barometric tube, perfectly dry, and fill it with mercury just boiled, marking the place (30) where it is stationary; then, having graduated the tube, I pour a little water or any other liquid, the subject of experiment, into it, so as to moisten the whole inside: after this I again pour in mercury, and carefully inverting the tube, exclude all air; the barometer, by standing some time, exhibits a portion of water of $\frac{1}{8}$ or $\frac{1}{10}$th of an inch, on the top of the mercurial column; because, being lighter, it ascends by the side of the tube, which may now be inclined, and the mercury will rise to the top, manifesting a perfect vacuum from air. I next take a cylindrical glass tube A B, open at both ends, of two inches diameter and fourteen inches in length, to each end of which a cork is adapted, perforated in the middle, so as to admit a barometer tube to be put through, and to be held fast by them; the upper cork is fixed two or three inches below the top of the tube, and is one-half cut away, so as to admit water, &c., to pass by, its service being merely to keep the tube steady. Things being thus circumstanced; water of any temperature may be poured into the wide tube, and thus made to surround the upper part or vacuum of the barometer, and the effect of temperature in the production of vapour within can be observed from the depression of the mercurial column at the top. In this way I have had water as high as 155° surrounding the vacuum; but as the higher temperatures might endanger a glass apparatus, instead of it I used the following:—


Having procured a tin tube A B, four inches in diameter and two feet long, with a circular plate soldered to one end, having a round hole in the centre, like the tube of a reflecting telescope, I got another smaller tube of the same length soldered into the larger, so as to be in the axis or centre of it; the small tube was open at both ends, and on this construction water could be poured into the large vessel to fill it, while the central tube was exposed to its temperature. Into this central tube I could insert the upper half of a syphon-barometer, and fix it by a cork, the top of the narrow tube also being corked—thus the effect of any temperature under 212° could be ascertained, the depres-


* Bodies are called *volatile* when they emit vapour at the ordinary temperatures of the atmosphere. Thus, oil of turpentine, ether, and camphor, are examples of volatile bodies. Bodies again which do not emit sensible vapour at low temperatures, as marble, iron, &c., are called *fixed*.

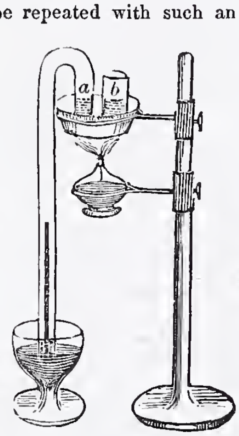
† This may be effected in various ways, but most easily thus: fill the tube *very nearly* with mercury, keeping the open end uppermost, and upon the surface of the mercury place a few drops of the liquid, the tension of whose vapour is to be discovered, observing that the mercury and liquid together *completely* fill the tube; then placing the thumb upon the open end, invert the tube, and place it in its position in the mercurial trough: the liquid being light, compared with the mercury, will ascend and float upon the surface of the mercurial column.

sion of the mercurial column being known by the ascent in the exterior leg of the syphon."

In this way tables of the elasticity of all vapours, at all temperatures below the boiling points of the liquids which yield them, may be formed; but as that referring to aqueous vapour is the only one of much importance, we insert it in preference to all others, as it serves both for use and illustration. It was originally constructed by Dr Dalton, but the results contained in it were subsequently confirmed by Dr Ure and other experimenters.

| Temperature. | Elasticity in inches of mercury. | Temperature. | Elasticity in inches of mercury. |
|---|---|---|---|
| 32° | 0·200 | 90° | 1·36 |
| 40 | 0·263 | 100 | 1·86 |
| 50 | 0·375 | 120 | 3·33 |
| 55 | 0·443 | 140 | 5·74 |
| 60 | 0·524 | 160 | 9·46 |
| 65 | 0·616 | 180 | 15·15 |
| 70 | 0·721 | 200 | 23·64 |
| 80 | 1·000 | 212 | 30·00 |

Dalton's experiments may easily be repeated with such an apparatus as that depicted on the margin. It consists of a glass tube about 36 inches in length, close at the end *a*, and bent. In this end the vaporizing liquid is contained, and the open end is immersed in a cup of mercury, the body of the tube being filled, as before, with that liquid.* Supposing that it is watery vapour which is experimented upon, the bent end of the tube dips into a vessel containing oil, in which is also placed a small glass vessel (a test tube for instance) containing a little water. Heating the oil by means of a spirit-lamp, it may be observed that the expulsion of the mercury from the tube coincides exactly with the commencement of the ebullition in the vessel *b*. Further, if the temperature of the water in the vessel *b*, be observed from time to time, it will always be found that the height of the mercury in the barometer corresponds with the table already given; that is, supposing the atmospheric pressure to be, at the time, equal to 30 inches of mercury, the height of the mercurial column in the table will be 30 inches diminished by the quantity given in the table opposite to the particular temperature. Thus, when the temperature is 180°, the height of the mercurial column is (30 — 15·15) inches, = 14·35 inches. All the results of the table may indeed be easily verified in this way, and similar tables made for other liquids than water. The experiment, moreover, affords a distinct explanation of the phenomenon of boiling. We observe, for instance, that water at a temperature of 200° sends off vapour with a force equal to 23·64 inches of mercury; and we know that, were this the measure of the atmospheric pressure, it would boil at that point; but, supposing a bubble of steam to form in it, the pressure being 30 inches, the bubble should be crushed by a force equal to the difference, namely, (30—23·64) inches = 6·36 inches of mercury, and consequently dispersed. But when the temperature rises to 212°, the elasticity is equal to the 30 inches, and then the external and internal pressures being the same, the bubble rises in the liquid and maintains itself at the surface until its investing film of water is ruptured, by other causes, and the vapour mixes uniformly with the air. It is the bursting of the steam bubbles formed before ebullition begins, that constitutes the simmering or singing of a boiler or kettle on the fire. "The bottom of the vessel heats



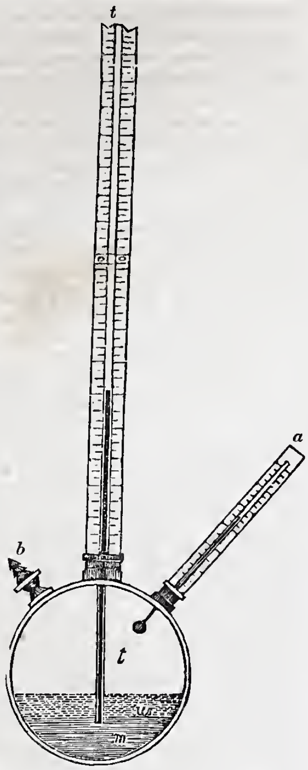

* The easiest way of preparing this experimental barometer for operation is,—introduce a little water into the bent end *a*, and place the open end in the cup of mercury; then make the water boil till steam rises up freely through the mercury, when the heat may be withdrawn. As the apparatus cools down, the steam will condense, and the mercury will rise in the tube by the force of the atmospheric pressure: it is now free of air, and ready for future experiments.

more strongly the layer of water in contact with it, so that the steam has there a high degree of elasticity, and forms a multitude of minute bubbles; when these separate from the hot metal, they are immediately burst in by the greater external pressure, and the mass of water is thus thrown into a state of exceedingly rapid and uniform vibration, which falls upon the ear so regularly, in many cases, as to produce a musical, and often agreeable tone, which may become graver or more acute, according as the bubbles burst more or less rapidly after one another."—*Kane's Chemistry.*

Before the experiments of Dalton set the matter at rest, it was very commonly believed that evaporation at low temperatures was owing to chemical attraction between the particles of air and the liquid; and the idea seems at first highly plausible, as a certain degree of affinity does to all appearance exist between air and water. When a portion of the liquid is exposed to the atmosphere, the evaporation is proportional to the extent of surface exposed, and is therefore greatly accelerated by increasing the surface, and by agitating the superincumbent air, as in the case of a brisk wind, either produced naturally or by artificial means. But, in the first place, the experiments described show that evaporation takes place *in vacuo;* and in the next, it is ascertained that the atmosphere positively retards the process; and that the very best means of accelerating it is to remove the air altogether. The experiments of Dalton have indeed proved that heat is the true and only cause of the formation of vapour, and that the actual quantity of vapour which can exist in any given space is dependent solely upon the temperature. This is proved from those cases wherein the evaporation takes place in a vacuum by the preceding experiments; but the same results are obtained when the space is filled with air as when it is vacuous, with this difference, that the repletion of the space with vapour proceeds more slowly when air is present. If, for instance, a little water be put into a dry glass flask, at a temperature of 32°, the flask will be found to contain a small quantity of vapour; at 40°, more vapour will exist in it; at 50°, it will contain still more; and at 60°, the quantity will be still farther augmented. And, it may be observed, that being at 60°, if the temperature be suddenly lowered to 40°, a portion of the vapour will be condensed, and the portion remaining will be precisely the same as when the temperature was originally at 40°. In this experiment it matters not whether the flask be full of air or vacuous; in either case the quantity of vapour formed is the same when the thermometer indicates the same temperature. The only difference remarkable is the rapidity of the evaporation. If the air be previously extracted out of the flask, it acquires its full complement of vapour in an instant, whereas the presence of air affords a mechanical impediment to its diffusion as if by a species of friction; and, therefore, an appreciable time elapses before the vaporous atmosphere attains its full degree of tension. Dr Dalton carried his experiments still further, and showed that the elasticity of vapour is always the same for the same temperature, however much the pressure may vary, there being liquid enough present to preserve the state of saturation proper to the temperature. For instance, if a little water be put into a flaccid bladder, and if the pressure upon its surface be diminished, the vapour in the interior will expand proportionally; and, consequently, will for the moment diminish the elasticity according to the known law, that the tension of aeriform fluids, at a constant temperature, diminishes in the same ratio that the volume increases; but the vapour in the bladder will speedily recover its original tension, by the water yielding an additional quantity of vapour corresponding to the increase of space. Again; if the pressure on the bladder be increased so as to diminish its capacity—the temperature remaining constant—the tension of the confined vapour will still continue unchanged, because a portion of it will be condensed proportional to the diminution of space. And this law holds good whether the vapour is pure or mixed with air or other gas.

From the table already given it is seen that the elasticity increases very rapidly with the temperature; in rising, for instance, from 180° to 212° the elasticity is doubled. For higher temperatures the rate of increase is still more rapid; so rapid, indeed, that experiments upon it can only be conducted safely with an apparatus provided with a safety-valve. This is a small lid in the upper part of the steam generator, properly loaded, according to the force of the steam to be generated; and this again must always have reference to the kind of material of which

the boiler is constructed. A very convenient apparatus for determining the elasticity at temperatures above the ordinary boiling point, within certain limits, is figured on the margin. It consists of a stout globular vessel containing mercury *m*, and water *w*, and having a long glass tube *tt*, open at both ends, firmly adjusted into it so as to dip into the mercury. The part of the tube which rises above the boiler has a scale attached to it, and graduated into inches and parts of inches. The globular vessel has two other openings, into one of which a stop-cock *b*, is screwed, and into the other a thermometer *a*, having its bulb within the vessel. When heat is applied to the apparatus, the vapour produced cannot escape, as all the junctions are perfectly steam-tight; the temperature, therefore, continually rises instead of stopping at the boiling point, and the vapour formed, pressing upon the surface of the liquid, and this again on the surface of the mercury beneath, forces the mercury to ascend in the tube *tt*, till it attains a height sufficient to counterpoise, by its weight, the elastic force of the steam. The height, therefore, to which the mercury is made to ascend, may be taken to express the pressure of the steam, that is, its elasticity at any temperature above 212°. As the weight of the atmosphere is equivalent to a column of mercury of 30 inches, this force must be overcome by the steam at 212°, before the mercurial gauge furnishes any indication. But this temperature being once passed, the mercury begins to rise, and every 30 inches it is forced up the gauge-tube denotes an increase in the elastic force of the steam contained in the apparatus equal to the pressure of *an atmosphere*. Thus, supposing the mercury to stand in the gauge at 30 inches, the steam is said to be of 2 atmospheres, at 45 inches, it is 2½ atmospheres, at 60 inches, it is 3 atmospheres; and so on. The thermometer, at the same time, shows the corresponding temperatures.




The elastic force of steam was, till lately, a fruitful source of experiment, when the subject was set at rest by a commission of the French Academy, appointed by the French government, and in which Dulong and Arago took a leading part. The results as given in the following table, were obtained by direct experiment up to a pressure of 25 atmospheres, and at higher pressures by calculation founded on the rate of progression observed at lower temperatures.*

| Elasticity of steam, taking atmospheric pressure as unity. | Temperature in degrees of hundredths of Fahrenheit's scale. | Elasticity of steam, taking atmospheric pressure as unity. | Temperature in degrees and hundredths of Fahrenheit's scale. |
|---|---|---|---|
| 1 | 212 | 13 | 380·66 |
| 1½ | 233·96 | 14 | 386·94 |
| 2 | 250·52 | 15 | 392·86 |
| 2½ | 263·84 | 16 | 398·48 |
| 3 | 275·18 | 17 | 403·82 |
| 3½ | 285·08 | 18 | 408·92 |
| 4 | 293·72 | 19 | 413·96 |
| 4½ | 301·28 | 20 | 418·46 |
| 5 | 308·84 | 21 | 422·96 |
| 5½ | 314·24 | 22 | 427·28 |
| 6 | 320·36 | 23 | 431·42 |
| 6½ | 326·26 | 24 | 435·56 |
| 7 | 331·70 | 25 | 439·34 |
| 7½ | 336·86 | 30 | 457·16 |
| 8 | 341·96 | 35 | 472·73 |
| 9 | 350·78 | 40 | 486·59 |
| 10 | 358·88 | 45 | 491·14 |
| 11 | 366·85 | 50 | 510·60 |
| 12 | 374·00 | | |

In order to understand such tables as this, it is necessary to observe that vapour when heated by itself, apart from the liquid which produced it, does not possess a greater elasticity than an equal quantity of air confined and heated to the same degree. A Papin's digester, for instance, if filled with steam at 212°, no water in the liquid state being present, may be heated to redness without danger of bursting. But if water be present, then every addition of heat causes an additional portion of steam to rise, which, adding its elastic force to that of the vapour previously existing, the pressure exerted upon the vessel soon becomes excessive. Thus, supposing that the apparatus is heated to 294°, the elasticity of the steam, when no water is present, would only be increased from 30 to 34 inches of mercury; but if water be present, the pressure becomes equal to four atmospheres, or 120 inches of the mercurial column. It must also be remembered, that the elasticity of a vapour cannot be really increased by any increase of pressure, as this simply causes a quantity of it to return to the liquid form, leaving the diminished space occupied by vapour of the original tension. If, however, instead of attempting to increase the pressure on a vapour, we diminish it, then the vapour preserves its elastic form, and its elasticity diminishes in all respects as if it were a permanent gas.

It is the common opinion that the density of vapours and their elastic forces are simply proportional to each other, as in permanent gases. The following and similar tables are calculated upon this principle.

| Temperature. | Elasticity in inches of mercury. | Density, taking air = 1000. | Weight of 100 cubic inches in grains. |
|---|---|---|---|
| 32° | 0·200 | 5·68 | 0·136 |
| 50 | 0·375 | 10·17 | 0·247 |
| 60 | 0·524 | 14·06 | 0·339 |
| 100 | 1·860 | 46·36 | 1·103 |
| 150 | 7·420 | 169·24 | 4·054 |
| 212 | 30·000 | 620·20 | 14·960 |

But there is much reason to suspect that this subject requires to be re-examined; the rules are, in fact, only applicable with certain limits. Despretz has shown, for instance, that the density of watery vapour at 67° is 7·72, whereas, according to calculation it is 17·26; and the curious experiments of Cagniard de la Tour show that the rule is still more erroneous for high temperatures. The method adopted in these experiments was to fill a small glass tube in part with the liquid to be operated upon, and to seal it hermetically. The tube was then exposed to heat, till the liquid passed entirely into vapour. Ether became gaseous in a space scarcely double its volume, at a temperature of 320°, and exerted a pressure of not more than 38 atmospheres, whereas by calculation, its elastic force should be 168 atmospheres. Alcohol became gaseous in a space about three times its volume, at the temperature of 404½°, and exerted a pressure of only 139 atmospheres, whereas calculation gives 221 atmospheres. Water

* The formula given by the Commission of the French Academy is

$$Ft = (1 + 0{\cdot}7153\,t)\,5$$

where F is the elastic force due to a certain temperature *t*. A committee of the Franklin Institute, in a still more recent investigation of the subject, gives the formula

$$Ft = (1 + 0{\cdot}00333\,t)\,6$$

The following is the table from which this formula was deduced:—

| Pressure. | Observed Temp. | Pressure. | Observed Temp. | Pressure. | Observed Temp. | Pressure. | Observed Temp. | Pressure. | Observed Temp. |
|---|---|---|---|---|---|---|---|---|---|
| Atmo. | Fah. ° | Atmo. | Fah. ° | Atmo. | Fah. ° | Atmo. | Fah. ° | Atmo. | Fah. ° |
| 1 | 212 | 3 | 275 | 5 | 304½ | 7 | 326 | 9 | 345 |
| 1½ | 235 | 3½ | 284 | 5½ | 310 | 7½ | 331 | 9½ | 349 |
| 2 | 250 | 4 | 291½ | 6 | 315½ | 8 | 336 | 10 | 352½ |
| 2½ | 264 | 4½ | 298½ | 6½ | 321 | 8½ | 340½ | | |

The results of this table may be compared with that given in the text.

became gaseous in four times its liquid volume at 773°, and should then, by the theory, have an elasticity of 780 atmospheres, which is greatly more than the glass tube employed could possibly have resisted. The experiments have since been repeated, with various modifications, but with strictly similar results. The conclusion, therefore, is, that the relation between the elasticity of a vapour and its density is not yet strictly ascertained. The rules referred to hold nearly true, however, when the temperature varies only a few degrees above or below the boiling point of the liquid.

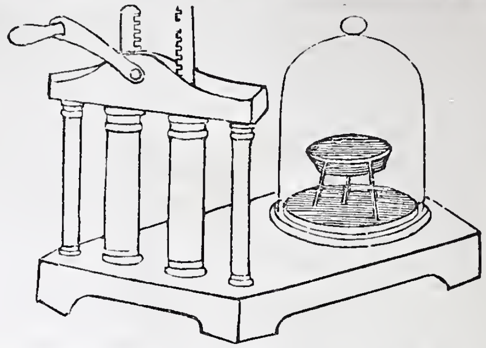
Whatever may be the density of steam, the same weight contains the same quantity of heat, that is, the sum of its sensible and latent heat is always the same. To understand this, it must be observed, that the lower the temperature at which evaporation takes place, the greater is the amount of heat absorbed and rendered latent by the vapour; and conversely, the higher the temperature at which evaporation is conducted, less heat becomes insensible. This accounts for the fact first ascertained by Watt, that distillation at low temperatures is not attended with any saving of fuel; but the true explanation was first given by Mr Sharpe of Manchester (*Manchester Memoirs*, 2nd Series ii.) His experiments, indeed, were confined to steam, from 212° upward, but they were speedily extended to aqueous vapour at temperatures downward to 0° by Clement and Desormes. The principle may therefore be regarded as thoroughly established for aqueous vapour of all temperatures; and it has been shown very satisfactorily by Despretz, that it holds likewise true of the vapours of some other liquids, as oil of turpentine, alcohol, and ether. Thus with water evaporating at

| | | | | | |
|---|---|---|---|---|---|
| 32° | the latent heat is | 1180° | then | 1180° + 32° | = 1212° |
| 100 | ... ... | 1112 | .. | 1112 + 100 | = 1212 |
| 212 | ... ... | 1000 | ... | 1000 + 212 | = 1212 |
| 250 | ... ... | 962 | ... | 962 + 250 | = 1212 |
| 300 | ... ... | 912 | ... | 912 + 300 | = 1212 |

This furnishes a ready mode of finding the latent heat of steam at any given temperature; all that is necessary being to subtract the sensible heat from the constant quantity 1212, and the remainder is the latent heat. Thus, for steam at 400° we have 1212° — 400° = 812° the latent heat.

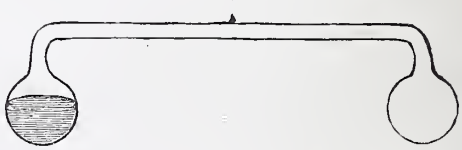
Although it is thus manifest, that there is no economy as regards fuel in evaporating at one temperature rather than another, as the same absolute quantity of heat is invariably carried off by the vapour, still there are cases in the arts where the process is better conducted at one temperature than another. Improvements in the mode of applying the heat may, indeed, as in the case of sugar refining, formerly alluded to, obviate the necessity of evaporating in vacuo; but there will always exist reasons for preferring very low temperatures in some processes of vaporization.

The great absorption of heat in the conversion of a liquid into vapour, explains why at low and common temperatures the processes of evaporation is attended with remarkable cold. "If a wet cloth is spread out in a keen wind, at a temperature a few degrees above freezing, the water by its rapid evaporation, soon carries off so much heat as to freeze the remainder, making the cloth hard and stiff, by the formation of ice within its pores." It is owing to the same cause, that a few drops of ether poured upon the hand, gives so intense a sensation of cold. This is particularly remarkable, when the hand is exposed to a current of air, as by blowing gently upon it, which facilitates the evaporation. Water, indeed, may be frozen by this means. If we fill a small thin glass tube with a little water, and roll round it a strip of muslin, and suffer ether to dribble upon it from a dropping bottle, at the same time that we accelerate the evaporation by blowing gently upon it with a pair of bellows, the water will speedily freeze. The experiment is more strikingly performed, by placing some ether in a shallow thin metallic cup, resting in a shallow glass vessel, containing a small quantity of water, and placing the vessels thus arranged under the receiver of an air-pump: during exhaustion the ether will *boil*, so rapid is its evaporation, and the water in the mean time will be frozen in consequence of its heat of fluidity being carried off by the ethereal vapour. On examination the two cups will be found firmly adhering together by an intervening sheet of ice.* There is a similar experiment beautifully illustrative of the freezing of water by its own evaporation, first suggested by Sir John Leslie. It consists in placing under the receiver of the air-pump, two flat dishes, one containing a little water placed at some height above the other, which contains sulphuric acid (oil of vitriol). To ensure success



the upper vessel should be of porous stoneware, and of small capacity; the under one may be of glass, and should expose a considerably greater surface. By exhaustion, the evaporation of the water is facilitated, but as vapour forms, it is absorbed by the acid, which has a great affinity for water, and thus after one good exhaustion the process proceeds without interruption, until so much heat is removed, that the remaining water is converted into ice. This process might be employed on a large scale for procuring ice in warm climates, as "the necessary vacuum could easily be commanded, by allowing the receivers to communicate with a strong drum filled with steam, which could be condensed." The acid again, when it became too dilute to act with sufficient power as an absorbent, could be restored to all its strength, by simply boiling it to drive off the water.

The *cryophorus* (ice-carrier)—an elegant little apparatus, invented by Dr Wollaston—illustrates the same general principle in a manner still more simple than that described. The instrument consists of a long tube terminating in bulbs which




contain some water. In making it, the air is first expelled by boiling the water in both bulbs at the same time, and allowing the steam to escape by a small opening at the extremity of the little projection on the tube at *a*. While the instrument is thus full of steam, the aperture at *a* is suddenly closed by fusing the glass around it with the blowpipe flame. In experimenting with it, all the water is brought into one bulb, and the other, that is the empty bulb, is immersed in a freezing mixture of snow and salt. The vapour in the cooled bulb is condensed there; and new vapour being formed in the water bulb as quickly as condensation takes place in the other, a rapid distillation proceeds from the one bulb to the other. The vapour which forms in the warm bulb deriving its latent heat from the water which remains behind, gradually cools it down to the freezing point, and congelation of the whole speedily takes place: "the latent heat of about eight parts of the water being given up to form the latent heat of one part of vapour at 32°." It is from this apparent transference of the cold of the bulb in the freezing mixture to the bulb at a distance from it, that the instrument derives its name.*

There are many cases in which we resort to accelerated evaporation as a source of cold, without carrying it so far as to produce ice. In sultry weather we sprinkle floors and pavements with water to cool them and the air, by its evaporation. The Spanish *alcarrazas*, and our *wine-coolers*, are earthen

* The success of this experiment is sometimes marred by the ether boiling over into the water, and preventing its congelation. This may be prevented by putting a bit of wood or paper into the ether, which causes it to boil regularly, and prevents sudden jets.

* The experiment sometimes fails in a warm and crowded lecture-room, on account of the rapid deposition of moisture upon the exposed bulb from the condensation of the warm vapour of the room. This, however, is easily prevented, by placing the water bulb in a glass vessel during the experiment, and covering the mouth of the vessel with a bit of paper, cloth, or the like.

vessels so porous, that water put into them filters through, and evaporating from the outside, cools the interior mass. The value of this process has been known in oriental countries from time immemorial, as a means of keeping water in a state sufficiently cool to be agreeable for drinking.

In some other liquids the spontaneous evaporation and freezing occur still more simply. A drop of strong prussic acid, for instance, pendant from the end of a glass rod, becomes solid by the evaporation of a portion of it cooling what remains; and the remarkable phenomena of the solidification of carbonic acid arises from exactly the same cause. The process is this: a small stream of the liquefied acid is allowed to escape from a magazine of the liquid, usually into a cylindrical box of wood; one portion immediately flashes, as it were, into gas, and absorbs so much heat, that the portion which remains is converted into a light powder like snow, which is the solid carbonic acid. This being a bad conductor of heat is not immediately dissipated by evaporation.

As evaporation is found to take place at very low temperatures, the question has been raised whether there is any point of temperature at which those bodies called volatile cease entirely to emit vapour? Previous to the researches of Mr Faraday, (published in the Transactions of the Philosophical Society, for 1826), on the limits of vaporization, the opinion was generally held that bodies which are decidedly vaporous at high temperatures never cease to evolve vapour, however far their temperatures are depressed, although the quantity emitted becomes continually less and less, till at length it ceases to be appreciable by our senses. Even fixed bodies, as metals, and rocks, have been supposed to allow an escape of their substance into air at the ordinary temperatures, and hence it was supposed, that the atmosphere must contain traces of the vapours of all bodies with which it is in contact. Mr Faraday, in his paper referred to, has established the opposite conclusion. Mercury, he found, yielded a small quantity of vapour during summer, at a temperature varying from 60° to 80°; but in winter, no traces of vapour could be detected. He similarly found that several chemical agents, volatilizable by a heat between 300° and 400°, did not undergo the slightest evaporation when kept in a confined space with moisture during four years. The conclusion therefore is, that all bodies cease to emit vapour at some particular temperature—the temperature being higher or lower according to the nature of the body. But the question occurs—what is it that puts a stop to vaporization? Mr Faraday founds his answer upon the principle laid down by Dr Wollaston, in his argument for the limited extent of the atmosphere. Since "the elasticity of any gaseous matter diminishes in the same ratio as its volume increases, it follows that whenever the tenuity of a portion of it, owing to its distance from the earth's surface or any other cause is exceedingly great, its tension is exceedingly small. It is easy therefore to conceive a limit where the loss of elastic force is so great that the mere gravity of the particles becomes equal to their elasticity, thus putting a stop to their further separation. The loss of tension necessary to induce this condition may be brought about in two ways:—by extreme dilatation and by cold. For substances of great volatility, such as air and most gases, the former condition is necessary, because the degree of cold which we can command on the earth's surface diminishes their tension in a degree quite insufficient to destroy their elasticity. But the volatility of numerous bodies is so small, that their vapour at common temperatures approximates in rarity to the air at the limits of the atmosphere; and a small degree of cold may suffice for rendering the elastic force inferior to the antagonizing force of gravity. Thus about 50° the elasticity of mercurial vapour is slightly superior to the gravity of its particles, but below 40° the latter power predominates and puts an entire stop to the evaporation of mercury. The earths and metals which are more fixed than mercury have vapours of such feeble tension, that the highest natural temperature is insufficient to convert them into vapour. There is besides another force which co-operates with gravity in overcoming elasticity: this is the attraction of cohesion. Liquids, we know, evince a certain degree of this attraction among their particles, and solids owe their solidity to the greater activity of this power among their particles. Keeping these two antagonizing forces in view, it is not difficult to conceive that the vaporizing power may be completely overcome and negatived at low temperatures, and no escape of particles in the vaporous form be permitted." Professor Graham suggests that this supposition is exactly conformable with the corpuscular theory of Laplace. According to that philosopher, the form of aggregation of a body depends upon the mutual relation of three forces:—1. The attraction of each particle for the other particles which surround it: this induces them to approach as near as possible to one another. 2. The attraction of each particle for the heat which surrounds the other particles in its vicinity. 3. The repulsion between the heat which surrounds each particle and that which surrounds the neighbouring particles—a force which tends to disunite the particles of bodies. When the first of these forces prevails, the body is solid; if the quantity of heat augments, the second force predominates; the particles then move among each other with facility, and the body is liquid. While this is the case, the particles are still retained by attraction for the neighbouring heat, within the limits of the space which the liquid body occupies, except at the surface, where the heat separates them, that is to say, occasions evaporation till the influence of some pressure prevents the separation from being effected. When the heat increases to such a degree that the reciprocal repulsive force prevails over the attraction of the particles for one another, they disperse in all directions, as long as they meet no obstacle and the body assumes the gaseous form. Berzelius further remarks in reference to the experiments of Cagniard de la Tour, already mentioned, that the reason why the elastic force observed differed so much from the results of calculation may be this: the particles not having an opportunity to recede much, the first two continue always to operate and oppose the tension of the gas, which does not establish itself in all its power, unless when the particles are so distant from each other as to be out of the sphere of the influence of these forces. These reflections must, however, be taken at their value—not as positively ascertained facts.

From what has already been adduced, we have no difficulty in regarding vapours as combinations of solids, or liquids with heat; and Mr Faraday's discoveries further sanction us in regarding gases as similarly constituted. Some of these are condensible by cold, and others by pressure into the liquid state, thereby showing that they are merely the vapours of extremely volatile liquids. Some gases, indeed, have resisted all efforts to coerce them into the liquid form. Oxygen, hydrogen, and nitrogen, for instance, have been subjected to a pressure of at least 800 atmospheres, not only without liquefying, but "without even deviating from the rule which implies perfect elasticity, and therefore without even approximating to the term at which they should abandon the gaseous state. But notwithstanding this, we cannot consider that there is any physical difference of constitution between these non-liquefiable and the liquefiable gases;" and hence we may conclude, that exposure to extreme cold and the application of a suitably increased pressure, would bring the constituent particles of *all* gases into coherent approximation and convert them into liquids. On the other hand we may regard a liquefied gas in its containing vessel to be circumstanced precisely like water heated in a digester far above its boiling point, and generating steam of great elastic force.

Mr Faraday's method of condensing gas is to subject it to the pressure of its own atmosphere. A strong glass tube close at both ends and a little bent in the middle, as represented in the figure,

is provided; but before it is completely closed at the bend, the materials for producing the gas are introduced—placing them in different ends to prevent the action from taking place before the tube is hermetically closed. When this is effected, all the materials are then made to pass into one end, and the action then commencing, the gas given off accumulates, and ultimately exerts so prodigious a pressure, as to liquefy in the end of the tube most remote from the materials. This may be artificially cooled to assist the condensation. Experiments of this nature are, however, attended with considerable danger from the bursting of the tube, and should never be attempted without sufficiently protecting the face with a wire-gauze mask, and the hands with thick gloves. The gases which have been liquefied in this way are, sulphurous acid, chlorine, cyanogen, ammoniacal gas, sulphuretted hydrogen, carbonic acid, muriatic acid, and nitrous oxide: and these require a degree of pressure varying in the different gases

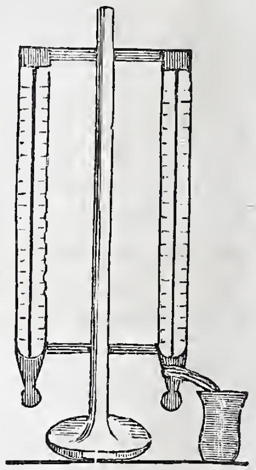
from 2 atmospheres, in the first mentioned to 50 atmospheres in the last named, at the temperature of 45°. Their elastic force varies, however, vastly, with the temperature. Thus liquid sulphuretted hydrogen exerts a pressure of 14 atmospheres at 3°, and 17 atmospheres at 47°; liquid muriatic acid at 22°, 32°, and 47° respectively, exert forces of 20, 25, and 40 atmospheres; and carbonic acid at 12° and 32°, forces of 20 and 36 atmospheres. This great increase of elasticity, limited to a few degrees of temperature, has led to sanguine opinions of their probable advantages as a source of power in machines; but no decisive experiments have yet been made of the practicability of their application.

Evaporation is a process of great importance in the economy of nature. All the accumulations of water upon the surface of the earth are subjected by its means to a natural distillation: the impurities with which they are impregnated remain behind; while the pure vapour ascends into the air, gives rise to a multitude of meteorological phenomena, and after a time descends again. It was formerly supposed that the atmosphere was essentially necessary to this spontaneous evaporation, but as already observed, the pressure of the air really retards it. It does nothing more, however; for, when a liquid gives off vapour, the quantity is determined solely by the space through which the vapour may spread, and the temperature: the only limiting cause to which evaporation is subject, is the pressure of the particles of the same kind, and therefore it is only necessary to know what quantity rises into a vacuum at any particular temperature—the same rises into air. Thus we have seen that vapour from water, which rises into a vacuum at 80°, depresses the mercurial column one inch; so if a bell-glass be filled with air over water at 80°, just so much vapour diffuses itself through the air as increases its elasticity 1-30th, or its bulk 1-30th if allowed to expand.

When air, saturated with aqueous vapour at a high temperature, is cooled, a portion of the vapour—depending upon the amount of depression—is condensed and precipitates in drops. It is upon such oscillations of temperature, combined with the continued evaporation going on at the earth's surface, that we depend for rain: were the atmospheric temperature constant, not a drop of rain would ever fall. This phenomenon of the condensation of atmospheric vapour may be observed on a small scale, by pouring very cold water into a dry glass tumbler in a warm room; the outside of the tumbler speedily becomes covered with moisture, and the reason is, that the air in contact with the glass is chilled, and its power to retain vapour is so much reduced, as to occasion the deposition of a portion of it upon the cooling surface. This, indeed, is the old experiment of Le Roi, for determining the quantity of vapour in the atmosphere. It is owing to the same cause that water is often seen in the morning running down in streams upon the inside of the glass panes of bed-room windows. The glass has the low temperature of the external air, and by contact cools the warm and humid air of the apartment, so far as to occasion the precipitation of a corresponding part of its moisture. Dew, as formerly explained, is caused in a similar manner.

As the temperature of the atmosphere is not constant, and as this condition would be necessary to its unvarying humidity, it becomes a problem of some importance to determine the amount of vapour at all times present in it. It is true that the thermometer would be a sufficient guide to us in estimating the degrees of saturation, did the changes take place so instantaneously that the full complement of vapour would always be present. But this is not the case, and accordingly we find that the air is excessively dry at one time, and at another it is fully saturated; and it varies in every possible degree of humidity between those extremes. This variable condition is ascertained by means of instruments, termed *hygrometers* (moisture-measurers). Of these there are various kinds; but they may all be referred to three principles. The construction of the first kind is founded on the property possessed by some substances of imbibing moisture and expanding in proportion to the quantity so imbibed, and of parting with it again to a dry air, and contracting as they dry. This property is common to wood, the beard of corn, whalebone, hair, parchment, and some other organic substances. Of these, none is better than human hair, which not only elongates freely from imbibing moisture, but by reason of its high elasticity, recovers completely its original length on drying. The hygrometer of Saussure is made with this material. To render the small alterations of length perceptible, an apparatus is contrived in which one of the extremities of the hair is made fast, and the other bearing a small weight surrounds the circumference of a cylinder which turns upon an axis to which a hand is adapted: this hand marks upon a dial, in large divisions, the almost insensible motion of the axis. The twisting and untwisting of cord and catgut, according as they imbibe moisture or give it out, are also used as hygrometrical measures. The Dutch toy called the weather-house, is made by suspending an index by a piece of catgut. The index is attached by the middle, and has the figure of a man on one extremity, and of a woman on the other; and it is placed so that the twisting of the catgut in wet weather sends out the man, and its untwisting in dry weather sends out the woman.

The second kind of hygrometer indicates the opposite states of dryness and humidity by the rapidity of evaporation. The principle is obvious: the more nearly the air is to saturation, the more slowly does the process of evaporation proceed, and no evaporation whatever takes place when the saturation is complete. We know also, that the rate at which evaporation proceeds, bears a fixed relation to the reduction of temperature induced, and this puts it effectually within our power to measure the quantity of vapour formed in a given time. The most convenient way of applying this principle is by covering the bulb of a thermometer with a piece of silk or linen, moistening it with water, and exposing it to the air: the descent of the mercury—that is, the degree of cold induced—corresponds to the quantity of vapour formed in a given time. The arrangement shown in the figure answers the purpose well. The apparatus consists of two delicate mercurial thermometers, the bulb of one of which is kept constantly moist, by a few threads looped round it, and dipping into a glass of water, while the bulb of the other is dry. The wet thermometer always denotes a lower temperature than the other, (unless when the air is fully saturated with moisture) and the difference of temperature shows the rate of evaporation going on. In making an observation the apparatus is generally placed in an open window where there is a slight current of air.

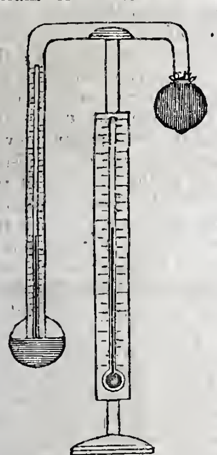


The third kind of hygrometer is upon a principle entirely different from the foregoing, and is much more simple. As already remarked, when air containing moisture is cooled down sufficiently far, a portion of its moisture is deposited upon the cooling surface. The experiment of Le Roi illustrates this, and indeed, gives a very simple mode of determining the particular temperature at which the quantity of vapour actually existing in the atmosphere would just amount to saturation: and this point at which the temperature and the quantity of vapour present in the atmosphere are just balanced, is what meteorologists call the *dew-point.* When the atmosphere is completely saturated, the dew-point and the temperature will coincide; for the least further diminution of the temperature causes a deposition of dew; but when it is very dry, a body must be cooled down several degrees before dew appears on its surface.

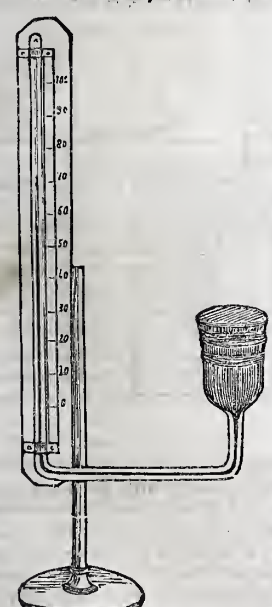
A very convenient apparatus for applying this principle is a very thin metallic cup, gilt on the outside and fitted into a case of turned wood lined with cloth, which serves as a stand for the cup during an observation. The cup should be capable of holding about half-an-ounce of water. A very delicate mercurial thermometer is also requisite. The cup being nearly filled with cold water, if no dew be immediately deposited upon its outside, a few grains of a powder prepared by mixing together equal parts of nitre and sal-ammoniac, may be added from time to time, stirring it all the time with the bulb of the thermometer, till dew begins to form. As soon as dew is deposited, the temperature is noted; and this first observation is corrected by waiting till the cup and its contents grow warmer, and observing the temperature at which the dew begins to disappear. This last observation is most to be depended upon; but when the ex-

periment is carefully performed, the mean of the two is still more accurate. The dew-point being thus ascertained, the absolute quantity of vapour which the air at the time of the observation possesses, may be learned by reference to a table of the tension of vapour of water at different temperatures. Thus, supposing the temperature 72°, and the dew-point 45°; the elasticity of vapour at 45° is 0·316 inch of mercury; and as the elasticity diminishes according as the volume increases, at 72° it is reduced to 0·3 inch of mercury; now, supposing the barometric pressure is 30 inches, the dry atmosphere balances 29·7 inches, and the watery vapour balances 0·3 inch, and the respective volumes are in the relation of these pressures.

The dew-point may be observed with still more facility by means of Professor Daniel's hygrometer. This is a cryophorus, modified somewhat in form, and containing ether instead of water. In one of the arms is placed a delicate thermometer, the bulb of which is immersed in the ether so as to indicate its temperature; the bulb of the other arm is empty and covered with muslin. The ether-ball is either made of black glass, or there is a zone of it gilt and burnished so that the deposition of dew upon it may the more readily be observed. When the instrument is to be used, the muslin is moistened with ether, and the cold produced by its evaporation condenses the vapour within the cryophorus, and causes the ether to evaporate rapidly in the other ball. The temperature of the ether-ball is thus gradually lowered, and in a short time, even in a very dry state of the atmosphere, dew begins to be deposited on its surface. This point is noted upon the enclosed thermometer, and compared with the atmospheric temperature shown by a thermometer attached to the stand of the instrument. To ensure correctness, the temperature at which the dew begins to disappear is also noted.



This instrument, which is very expensive, has been considerably simplified by Mr. Jones of London. The modified form is represented by the figure on the margin. It consists of a delicate mercurial thermometer, with its tube bent so as to bring its cylindrical bulb parallel with, and at a little distance from the stem. This bulb is an inch long, and is terminated by a flat surface of black glass, which projects a little beyond the circumference of the bulb; below this flattened surface the bulb is covered with muslin. When used, the temperature of the air is first noted: then, the muslin being moistened with ether, the temperature falls, and the clear black surface of the extremity of the bulb is soon rendered dim by the deposition of dew. The temperature indicated at that instant is the dew-point.

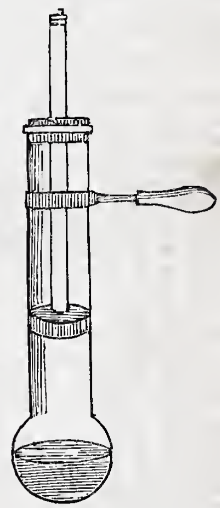


Professor Connell, of St. Andrew's, has lately invented a Dew Point Hygrometer, consisting of a little bottle of brass polished externally, and connected with a small exhausting syringe. Ether is introduced into the bottle, and a thermometer inserted, fitting into it by an air-tight ground stopper.

There is only one objection to this instrument, and it applies to all its forms—the difficulty of observing the incipient condensation. The surface on which the dew deposits is small, and requires a peculiar light to be readily observed; while the attention of the observer, distracted between the close inspection of the dew surface and the thermometer, is not able always to fix, with absolute precision, the dew-point. There is, however, a still more serious objection among the generality of observers to the *wet-bulb* hygrometer, described as the second kind. This is the want of an easy rule for calculating the dew-point from the difference of temperature indicated by the two thermometers. The formula of Dr August, which we shall place below, is universally acknowledged to be correct, but it is nearly as universally admitted to be of too difficult application for common use, especially in this country.*

It is not only necessary for some purposes that we know the hygrometrical condition of air and gases, but also to be able to deprive them entirely of their vapour. This may be done to a great extent by exposing them to intense cold; but the mode commonly adopted is, to bring the moist gas into contact with some substance which has a powerful affinity for water. The best and cheapest substance of this kind is chloride of calcium. Alcohol may be concentrated in an analogous manner. Suppose a shallow dish of dilute alcohol placed under the receiver of an air-pump along with a quantity of quick-lime; the air being exhausted, both the water and the alcohol begin to evaporate very rapidly, but the watery vapour is absorbed by the lime as quickly as it is generated, whereas no such absorption of the alcoholic vapour takes place. The consequence is, that a continual evaporation of the water is kept up, whilst the alcohol, after generating as much vapour as fills the receiver, cannot give off more. In this way alcohol may be obtained almost quite pure, its solution being evaporated, as it were, to dryness.

As air takes some time to become saturated with humidity, heated air, when employed in drying, should always be permitted to remain some time in contact with the wet goods before it is allowed to escape into the atmosphere. In the bleacher's stove, for instance, means ought to be taken to repress rather than promote the exit; otherwise it may pass off with only a very small portion of the humidity for which its temperature gives it a capacity, and thereby occasion a needless waste of fuel. In evaporating water by heated air, it must also be borne in mind that the vapour itself carries off just as much heat as if it were given off by boiling water, while the air associated with it requires also to have its temperature raised, and thereby occasions an additional consumption of heat. In this way, therefore, water can never be evaporated with so small an expenditure of fuel as in a close boiler. This applies also, in some measure, to those cases of evaporation, where the surface of the liquid is left entirely open to the action of the atmosphere. By this arrangement, there is a loss both of time and fuel.



The application of steam as a moving power in the steam engine, is made upon two different properties —the expansive force communicated to the steam by heat, and its ready conversion into water by cold. The effect of both these properties is well illustrated by the little instrument depicted in the margin. It consists of a glass tube an inch or so in diameter, and six or eight inches long, and blown into a spherical en-

* Dr. August's formula for deducing the elasticity of the watery vapour in the air, from the difference of temperature indicated by a wet and dry thermometer:—

Let $x$ = the elasticity of the vapour in the atmosphere, and which is to be found,
$e$ = the elasticity of vapour at the temperature indicated by the wet-bulb thermometer, taken from table,
$b$ = the barometrical pressure, the normal pressure being 336 lines,
} in Parisian lines.

$d$ = the temperature of the dry thermometer,
$w$ = the temperature of the wet thermometer,
} by Reaumur's scale.

Then for temperatures above the zero of Reaumur we have,

$$x = e - \tfrac{3}{8}(d-w) - 0{\cdot}0011\,(336-b)\,(d-w)$$

And for temperatures below the zero of Reaumur,

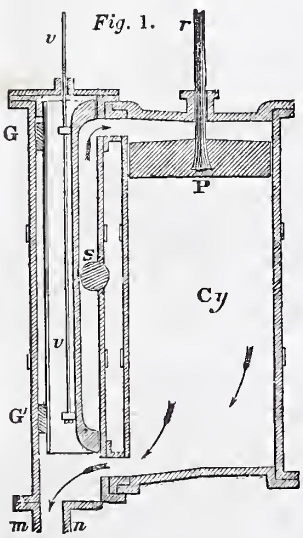
$$x = e - \tfrac{1}{3}(d-w) - 0{\cdot}001\,(336-b)\,(d-w)$$

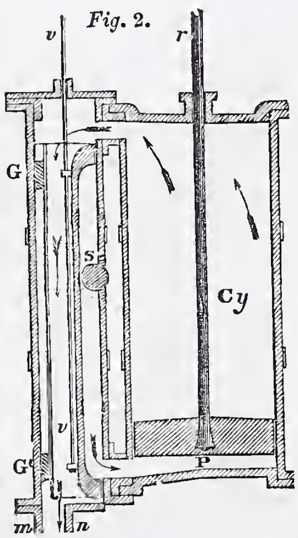
As an example, suppose that the dry thermometer is at 19°·1 R. and the wet one at 11°·1 R, there is a difference of 8° R. The elasticity of vapour at 11°·1 R. is 5·56 Parisian lines. Suppose now that the barometer stands at 338 lines, and the first formula becomes,

$$\begin{aligned} x &= 5{\cdot}56 - \tfrac{3}{8}(19{\cdot}1 - 11{\cdot}1) - 0{\cdot}0011\,(336 - 338)\,(19{\cdot}1 - 11{\cdot}1) \\ &= 5{\cdot}56 - \tfrac{3}{8} \times 8 - 0{\cdot}0011 \times -2 \times 8 \\ &= 5{\cdot}56 - 3 + 0{\cdot}0176 = 2{\cdot}5424 \end{aligned}$$

The elasticity of the vapour is therefore equal to a mercurial column of 2·54 Parisian lines. In the calculation it will be observed that the numbers expressing the temperatures are taken as simple numbers.

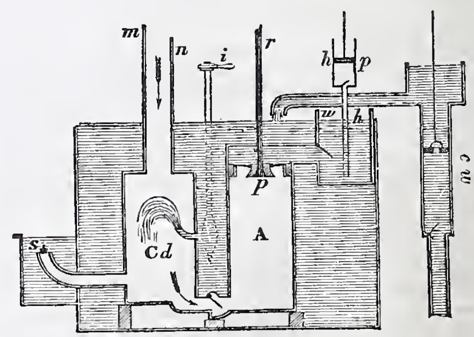
largement at one end. A piston is accurately fitted to the cylinder so as to move up and down freely, but air-tight. It is made by twisting tow round the end of a straight wire, and adding a little grease to lessen the friction. Some water is now put into the bulb, and made to boil till the steam issues freely; the instrument is then withdrawn from the source of heat, and the piston is entered into the mouth of the cylinder. Thus adjusted, let the steam be condensed by cooling the apparatus, and the piston will descend, apparently of its own accord, but really because it is forced down by the atmospheric pressure, the interior of the apparatus becoming vacuous by the condensation of the steam. Again; let the bulb be placed over the spirit-lamp, or other source of heat employed, and as steam generates, the piston will be observed to rise, and it will continue to approach the top of the cylinder even though loaded with a weight of several pounds.* The piston having reached the top, let the steam be again condensed, and again will the piston descend, even against a resistance of several pounds. Thus, by the alternate application of heat and cold, the same movements are reproduced, and may be continued for any length of time. This simple apparatus gives a very correct notion of the application of steam, in the old form of the steam-engine. The only essential difference is, that the engine had a boiler in which the steam was generated; but the condensation was effected in the cylinder by injecting cold water into it below the piston, which then descended by the pressure of the atmosphere upon its upper surface. Upon this Watt made two capital improvements: he introduced a separate vessel, in which the condensation is effected, and so modified the construction as to admit steam to act above as well as below the piston. The first of these improvements is of great importance, as it prevents the cylinder from being cooled down by the condensing water, and wasting the heat of the next portion of steam admitted to heat it up again; and the second allows of a vacuum being formed both above and below the piston, of which equal advantage may be taken. The following diagrams show how this is effected :—




These figures show vertical sections of the cylinder, valve, and halve-chest, and may be briefly explained thus :—C *y* is the steam-cylinder, a cast iron vessel turned perfectly cylindrical. In this works the piston P, shown at the top of the cylinder in fig. 1, and at the bottom in fig. 2. The cylinder has two openings, or *ports*, for the ingress and egress of the steam, but is otherwise perfectly steam-tight. S is a cross section of the great steam-pipe which delivers the steam from the boiler. It opens into the valve-chest, and has its capacity regulated by a valve placed in it, called the *throttle-valve.* In the valve-chest, which is shown a little longer than the main cylinder, is placed the valve. Of this there are many modifications, but that shown in the figure is perhaps the most common; and being semicylindrical in its form, and hollow, it is called, from the appearance of its cross section, the D-valve. That shown is, moreover, called the long D-valve, to distinguish it from another form called simply the D-valve. Towards the ends, the semicircular side of the valve is polished, and rendered truly cylindrical, so as to move easily, yet steam-tight, in the packings shown in cross section at G G'. The packings are composed of soft elastic hemp, soaked in oleaginous matter, and their use is, by pressing against the outside of the slide-valve when in its place, to make steam-tight partitions in the valve-chest between the middle and ends of the valve, so that the steam, from the steam-pipe S, cannot communicate with *both* ends of the valve at the same time. This will be understood by observing the direction of the arrows in the figures. In fig. 1, which shows the slide and piston in their highest position, the steam ascends from the steam-pipe along the centre of the slide and enters the upper port above the piston, but is prevented from passing downward by the packing at G'. In this position, therefore, the piston is subject to a downward pressure, equal to the pressure of the steam in the boiler; at the same time it will be observed that the steam is rushing from beneath it through the lower port into the eduction-pipe *m n*, which leads to the condenser. The piston is in consequence forced to descend, and assume the position it has in fig. 2. But, at the same time that the piston descends, the slide-valve is made also to change its position by means of the valve-rod *v v*, which has a properly adjusted connexion with the engine. In this position the steam from the steam-pipe has access to the lower port, while the steam is allowed egress through the upper port into a passage in the slide, indicated by the descending arrows, and thence, as before, into the eduction-pipe *m n*. The piston is, therefore, ready to begin its ascent, and assume the position shown in fig. 1. In this way the operation of the piston is continued, and the steam consumed at each stroke only exceeds the capacity of the cylinder by what is necessary to fill the passages between the slide and the cylinder.

The condensing apparatus and its appendages are still more simple.

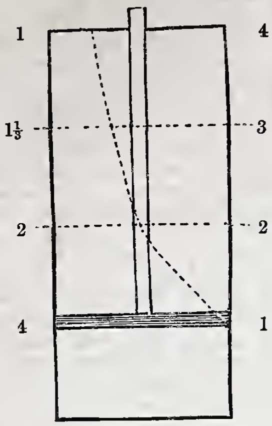



C *d* is the condenser into which the used steam passes through the eduction-pipe *m n*. A is the air-pump with its piston P, for drawing off the injection water, and the water of the condensed steam: it communicates with the condenser by a *foot-valve*, seen in the figure but not marked. *h w* is the hot-water well from which the boiler is supplied by means of the pump *h p;* it receives the water drawn off by the air-pump. *c w* is the pump to furnish cold water to the condensing cistern; *i* is the injection cock; *s* the blow-through valve.

The difference between a high-pressure engine and a low-pressure one lies, in the former being worked by the force of steam acting upon the piston, despite of the pressure of the atmosphere; the steam is consequently required to have a considerably greater elastic force than in a low-pressure engine. In the high-pressure engine, the steam being blown off into the atmosphere, the condensing apparatus is dispensed with, and the engine, as a whole, is considerably simplified. All locomotive engines are upon the high-pressure principle.

* Any of our young friends trying the experiment, must, however, remember that the apparatus is glass; they must, therefore, both load it lightly, and see that the piston works freely. An explosion might be serious, notwithstanding the smallness of the apparatus.

The expansive property of steam allows of a considerable saving to which we have made no reference above. Thus, suppose the annexed figure to represent the section of a cylinder, into which steam, at a tension of 4 atmospheres, is admitted till it fills one-fourth, when it is cut off. We may suppose that the piston is loaded. The steam of 4 atmospheres contained in the one-fourth of the cylinder, through which the piston has been raised, will expand, and the piston will continue to be lifted. By the time it occupies one-half of the cylinder it will be reduced to steam of two atmospheres; for it now occupying double space, its tension will be reduced one half; by the time it has elevated the piston three-fourths its elasticity will be $\frac{3}{4}$ or $1\frac{1}{3}$ atmospheres; and at the top of the cylinder the piston will have steam below it of $\frac{4}{4}$ or 1 atmosphere. During the action, the piston has, therefore, been elevated three parts of its progress by a force gradually diminishing from four atmospheres to one; that is, with an average force of two atmospheres, by steam that had previously produced its usual effect. The part of the figure cut off on the left by the dotted curve may be supposed to represent, geometrically, the continually diminishing elasticity of the steam.




This illustration does not pretend to perfect accuracy in the calculation; but it is sufficiently correct to show what is meant by using steam expansively, and the saving effected by the practice.

## MATHEMATICS.

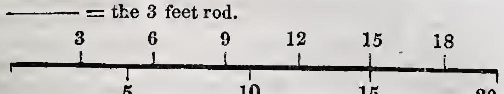
### CHAPTER V.

#### MULTIPLES AND DIVISORS.

[The subjects of this chapter are in themselves of little importance, but they are most essential as a preparation for fractions, which we now approach. The operations to be performed are really not difficult, and we shall endeavour to explain the principles involved, as clearly and simply as possible. It is to be remarked, however, that some of them hardly admit of elementary proof; and for this reason they are usually omitted altogether in arithmetical books.]

1. When one number divides another without leaving any remainder, or is contained in it an exact number of times, it is said to be *a measure* of that number, or to *measure* it; and again, a number that is measured by any other is called a *multiple* of that other. To understand distinctly the meaning of these terms and their connection, let us suppose that we have a log of wood of considerable length to measure, and that we are provided with two rods, one three feet, and the other five feet long, but without any divisions marked upon them. It is obvious that we will only be able to effect the required measurement, should it so happen that the length of the log is some determinate number of times the length of one of the rods. Thus, supposing we try the three feet rod, and after measuring off six times its length, find that there is a portion of the length to be measured remaining, which is less than another length of the rod; the measure employed fails for it does not inform how much shorter the unmeasured portion is than 3 feet: all that we learn is, that the log is more than 18 feet long, and less than 21 feet. But suppose that on applying the 5-feet rod we find that it measures the length of the log, for this is neither more nor less than four times its length. We are therefore satisfied that the length of the log is just 20 feet. This is found by multiplying the *measure* 5 feet by 4, the number of times it is contained, and this is what we mean by saying, that 20 feet is a *multiple* of 5 feet. But the same mode of reasoning may be employed whatever sort of units 5 and 20 are composed of; 20 gallons, for instance, can be measured by means of a 5-gallon vessel, but not by a vessel of 3-gallon capacity. We may therefore conclude, without regard to the application of the numbers, that 5 measures 20, and that 20 is a multiple of 5. What then is to be distinctly understood is this: *measure* is a particular name for a divisor, which leaves no remainder, and *multiple* for a number which is made by multiplying two or more others together.

——— = the 3 feet rod.




————— = the 5 feet rod.

2. We have here shown that 5 is a measure of 20, but it is not the only measure: for 2, 4, and 10, are also divisors of 20, which leave no remainder, and even 1 and 20 come within the meaning of the term, the first giving a quotient 20, and the latter a quotient 1. Therefore 1, 2, 4, 5, 10, 20, are all measures of 20, and consequently 20 is a multiple of these numbers. When a number, however, has no other measures than 1 and itself, it is called a *prime number*. Of this character are the numbers in the following table:—

| | | | | | |
|---|---|---|---|---|---|
| 1 | 11 | 29 | 47 | 71 | 91 |
| 2 | 13 | 31 | 53 | 73 | 97 |
| 3 | 17 | 37 | 59 | 79 | 101 |
| 5 | 19 | 41 | 61 | 83 | 103 |
| 7 | 23 | 43 | 67 | 89 | 107 |

None of these can be divided exactly by any other number than itself and 1.

3. It is often of importance to ascertain whether a given number is a prime number or not. To satisfy ourselves on this head, the only way of proceeding is to try if we can find some number that will measure it; if we are sure that it has no other measure than itself and 1, we are of course sure that it is a prime. This process may appear laborious, and so it is when the number is large, but still it may be done, and the work is facilitated by the following considerations:—

1°. The greatest factor which a number can have, is its half: should it therefore have a factor so great, it must be divisible by 2.

2°. If a number be divisible by any other, it is divisible by all the factors of that other. (Chap. IV. art. 13.)

3°. If a number be not divisible by any prime number, not greater than its square root,* it is not divisible by any number whatever, and is therefore itself a prime number. Thus 119 is a prime; for it is not measured by 2, 3, 5, or 7, and the next prime number 11 is greater than its square root, being $11 \times 11 = 121$.

4. We may take now one example of the decomposition of a number into its *prime factors*. Let the number be 1260. The question is to find out of what factors it is the product: it is therefore obvious that all these factors must be measures of it. For convenience; begin by trying as divisors the lowest prime numbers given in the foregoing table, employing each as often as it will succeed. In the example we find that 2 succeeds twice, 3 twice, and 5 and 7, each once. The simple measures then of 1260 are 2, 2, 3, 3, 5 and 7, and these are what we term its prime factors. We may therefore write

| | |
|---|---|
| 2 | 1260 |
| 2 | 630 |
| 3 | 315 |
| 3 | 105 |
| 5 | 35 |
| 7 | 7 |
| | 1 |

$$1260 = 2 \times 2 \times 3 \times 3 \times 5 \times 7$$

In the same way the student may prove that

$255 = 3 \times 5 \times 17$ $\quad$ $1035 = 3 \times 3 \times 5 \times 23$

$518 = 2 \times 7 \times 37$ $\quad$ $714 = 2 \times 3 \times 7 \times 17$

5. Two numbers are said to be *prime to each other* when they

* By *square root* is meant a number which, being multiplied into itself, gives a product equal to the number. Thus 5 is called the square root of 25, because 5 times 5 = 25. The method of finding the square root of a number accurately requires yet to be explained, but in the meantime the mere definition is enough for our purpose.

have no factor in common, and are consequently not *both* measured by any other number than 1. Thus 21 and 40 are both composite numbers, but they are prime to each other, for

$$21=3\times 7 \text{ and } 40=2\times 2\times 2\times 5$$

and thus no factor of the one number is a factor of the other. On the other hand, when a factor of the one number is found in the other, that factor is called a *common measure.* Thus supposing the numbers are 360 and 275, then

$$360=2\times 2\times 3\times 5\times 5 \text{ and } 275=5\times 5\times 11$$

from which it appears that the factors $5\times 5$ are common to the two numbers,—they have therefore a common measure $=25$. This is also the greatest common measure of the numbers; for none of the other factors being common, were the $5\times 5$ withdrawn; that is, were each number divided by this measure, the quotients would be prime to each other, and admit of no common measure greater than 1.

$$\text{Thus, } 360\div 5\times 5=2\times 2\times 3 \text{ and } 275\div 5\times 5=11.$$

6. This method of determining the greatest common measure may be practised upon other numbers : but although exceedingly simple in principle, it is laborious in practice, when the numbers are large, and is therefore usually abandoned for a method which is more direct. In order to explain this method we must in the first place state the following principles.

1°. If a number measures two others, it measures their sum and difference. As an instance, 8 measures 32 and 136 ; it therefore measures $136+32=168$ and $136-32=104$. (Chap. IV. art. 4.)

2°. If a number measures another, it measures any multiple of that other. For example, 5 measures 15, it therefore measures $15\times 2=30$ ; $15\times 3=45$ ; $15\times 4=60$ ; &c. (Chap. IV. art. 6.)

7. From these principles we readily deduce the following :—

1°. Every common measure of a dividend and divisor is also a common measure of the divisor and remainder. To show this let 216 be divided by 96. The quotient is 2, and the remainder 24 ; that is, $216=96\times 2+24$. From this it follows, that $96\times 2$ is just 24 less than 216, or that $216-96\times 2=24$. Taking now any number, as 8, which measures 216 and 96 ; then because it measures 216 and 96, it measures 216 and $96\times 2$, and also their difference which is 24 ; therefore every common measure of 216 and 96 is also a measure of 96 and 24. The same reasoning may be applied to all the common measures of 216 and 96 and the remainder 24, and therefore to their greatest.

2°. Every common measure of the remainder and divisor is also a common measure of the dividend and divisor. Observe in the foregoing example that $216=96\times 2+24$, and take any common measure as 12, of the remainder 24 and divisor 96. Then because 12 measures 24 and 96, it measures 24 and $96\times 2$ and their sum $96\times 2+24$ which is the dividend 216. As this reasoning applies to all the common measures of the remainder and divisor, it follows that these numbers have no common measure which is not also a common measure of the divisor and dividend.

By 1°, then, it is proved that the remainder and divisor have all the common measures which the dividend and divisor have, and by 2° it is proved that they have no others. Consequently, the greatest common measure of the dividend and divisor is also the greatest of the divisor and remainder. To show how these principles are applied, let us take a question, and for convenience let g. c. m. stand for the words *greatest common measure.*

What is the g. c. m. of the numbers 1133 and 231 ?

Dividing 1133 by 231, we get for remainder 209
Dividing 231 by 209, we get for remainder 22
Dividing 209 by 22, we get for remainder 11
Dividing 22 by 11, we get for remainder 0.

Since then 11 divides 22 without remainder, and since it is the greatest number which divides itself without remainder,

| | | |
|---|---|---|
| Therefore | 11 is g. c. m. of 22 and 11 | |
| But g. c. m. of 22 and | 11 is g. c. m. of 209 and 22 | by 1° |
| g. c. m. of 209 and | 22 is g. c. m. of 231 and 209 | by 1° |
| g. c. m. of 231 and | 209 is g. c. m. of 1133 and 231 | by 1° |
| Therefore | 11 is g. c. m. of 1133 and 231 | by 2°. |

8. This process is carried on as shown below, and directed in the following rule, called the rule for finding the greatest common measure of two numbers :

I. *Divide the greater of the two numbers by the less, until a remainder is obtained which is less than the divisor.*

II. *Make the remainder thus obtained a divisor, and the former divisor a dividend, and proceed as in I. to find another remainder.*

III. *Continue in this way, always dividing the preceding remainder by the last obtained, until one is obtained which exactly divides or measures the preceding remainder. This last divisor is the common measure sought.*

```
231 ) 1133 ( 4
       924
      209 ) 231 ( 1
            209
            22 ) 209 ( 9
                 198
                 11 ) 22 ( 2
                      22
                       0
```

∴ g. c. m. is 11.

IV. *Should the process not terminate until the last divisor is* 1, *the numbers are prime to each, or they admit of no other common measure than* 1.

The following numbers may be proposed for exercise in this rule :—

| Numbers proposed. | | g. c. m. | Numbers proposed. | | g. c. m. |
|---|---|---|---|---|---|
| 1261 | 1313 | 13 | 3760 | 9024 | 752 |
| 833 | 15785 | 7 | 791 | 8989 | 1 |
| 143 | 1271 | 1 | 5537 | 62923 | 7 |

9. We are sometimes required to find the g. c. m. of more than two numbers, and when this happens, the same rule is still applicable, thus : Find the g. c. m. of the first and second numbers, and of this c. m. and the third number. This is evident for the g. c. m. of the first and second contain *all* the common divisors of these numbers and no others ; whatever factor then is common to all the three numbers, is also common to the third number and to the g. c. m. of the first and second, and no others. The same reasoning may be extended to four and more numbers.

10. For similar reasons that it is desirable to be able to find the greatest common measure of numbers, it is desirable to have a method of determining their *least common multiple.* From what has been already advanced, it is very obvious that the product of two numbers is a multiple of the two. For instance, $9\times 12$, or 108, is a common multiple of 9 and 12. But it is not the least : for 36 and 72 are also multiples, and they are less than 108. To show how a less common multiple is found, observe that $9=3\times 3$, and that $12=3\times 4$ ; the g. c. m. of the numbers is therefore 3. Then $9\div 3=3$, and $12\div 3=4$ ; and these quotients 3 and 4 being multiplied together, and the product being multiplied by the g. c. m. gives $(3\times 4)\times 3=36$, which is a common multiple of 9 and 12. It is also the least common multiple ; but we cannot prove that it is necessarily so, as the demonstration to be understood requires some knowledge of algebra. But this is not of much importance, as in all cases where a common multiple is to be used, any one will do, and it is not even necessary that we should know that it is the least that we employ. The advantage of using the least common multiple rather than any other, is that in some operations we thereby work with smaller numbers than we otherwise would do. The results are however the same—just as the change of a sovereign is the same whether told down in 20 shillings or 240 pence. Although then we may satisfy ourselves in every case that the following methods give the least common multiple of the numbers proposed, we may simply regard them as convenient practical rules for finding such common multiples as will serve our purpose.

I. When the numbers proposed have no other common measure than 1, their product is their common multiple. Thus, $53\times 103$ are prime numbers, therefore their c. multiple is $53\times 103=5459$.

II. When the numbers proposed have a common measure, divide their product by it, and the quotient will be the c. multiple sought.*

Thus, 360 and 210 have a c. measure 30, therefore their c. multiple is $(360\times 210)\div 30=2520$. The reason of this appears when we consider that $210=2\times 3\times 5\times 7$, and that $360=2\times 2\times 2\times 3\times 3\times 5$ ; so that no number less than $2\times 2\times 2\times 3\times 3\times 5\times 7=2520$ can be measured by both the given num-

* The easiest way of putting this rule into practice is to divide *one* of the numbers by the c. measure, and to multiply the other number by the quotient.

bers; but $2\times2\times2\times3\times3\times5\times7$ is their product with $2\times3\times5$ struck out of it: that is, their product divided by their g. c. m.

To extend this rule to more than two numbers, find a c. multiple of the first two, then of that c. multiple and the third number; and so on.

III. It frequently happens that a c. multiple of several small numbers is required, and when this is the case, the best method of proceeding is as follows:—Suppose the given numbers are

7 2 8 5 15 3 12 18 21

Strike out all those numbers which are evidently divisors of some of the others, as 7 which divides 21; 2 and 3 which are found in 12; and 5, which is a factor of 15. The remaining numbers are

8 15 12 18 21

Resolve all these into their prime factors as follows:—

$2\times2\times2 \quad 5\times3 \quad 3\times2\times2 \quad 3\times3\times2 \quad 3\times7$

Take now each prime factor as often as it occurs in that one of the preceding which has it most often, but no oftener: this gives

2 2 2 3 3 5 7

Multiply all these together, which gives

$$2\times2\times2\times3\times3\times5\times7=2520$$

the c. multiple required for the given numbers.

This is fully more conveniently done by dividing successively by the prime factors. Thus, neglecting 7, 2, 3, and 5, as before, because every multiple which is common to the other numbers of which they are simply factors, must be common to them also; and arranging the operation as at the side, we divide successively such numbers as will divide by the prime factors; and by each as long as possible; and bringing down the other numbers, we proceed in this way till the whole of the dividends disappear. When this is accomplished, the product of the prime factors employed as divisors is the c. multiple sought. These, it will be observed, are the same by the last process as by the first; or rather they are the same by both ways of writing the same process.

| | | | | | |
|---|---|---|---|---|---|
| 2 | 8 | 15 | 12 | 18 | 21 |
| 2 | 4 | 15 | 6 | 9 | 21 |
| 2 | 2 | 15 | 3 | 9 | 21 |
| 3 | 1 | 15 | 3 | 9 | 21 |
| 3 | | 5 | 1 | 3 | 7 |
| 5 | | 5 | | 1 | 7 |
| 7 | | 1 | | | 7 |
| | | | | | 1 |

Practice will suggest to the student several abbreviations in all the processes of this chapter, and especially in such operations as the last. We have not noticed any of these, because we cannot think of one which will not occur spontaneously as soon as that familiarity with the principles is attained which would render its use advisable.

We subjoin a few cases for exercise on the rules for finding a c. multiple:—

| Numbers proposed. | Common multiple. |
|---|---|
| 12 16 30 | 240 |
| 16 18 22 | 1584 |
| 56 512 | 3584 |
| 98 716 | 35084 |
| 3 7 5 14 15 20 | 420 |
| 14 7 9 21 18 36 42 | 252 |
| 8 13 17 11 6 15 | 291720 |
| 144 210 360 | 5040 |
| 864 876 | 63072 |

# ANATOMY AND PHYSIOLOGY.

## CHAPTER VI.

### THE MUSCLES AND MUSCULAR ACTION.—*Continued.*

The human body, in a healthy state, is powerful or weak in proportion to the strength or exhaustion of the muscles. Muscular exercise increases muscular power; muscular inaction produces muscular debility. If muscles are actively and constantly employed, they become more powerful than if accustomed to inactivity and rest. The brawny muscles of a blacksmith's arm, are more potent than those of a lawyer's clerk. The muscles of the legs, feet, and toes, of a professional dancer are more active and nimble than the same muscles in the lower extremities of a tailor. The dancer daily exercises them for the acquisition of his bread; the tailor, when at work, permits them to lie at rest. The stage-buffoon, who excels in grimaces, constantly employs his facial muscles to distort his face, and acquires astonishing control over their motions. The Quaker, on the other hand, permits them to remain inactive, (as he wishes to appear grave,) and partly loses control over their action. Some muscular porters in Constantinople will with ease carry a load on their shoulders of eight hundred weight, which would almost press half a dozen of muslin weavers or tailors to the ground.

The rapidity with which an expert flute-player moves his fingers over the holes of his flute, is the effect of the active and acute motion of the muscles of his fingers, acquired by long and constant practice; and if contrasted with the first awkward essays of the sluggish fingers of a clown rudely playing on his flute, may exhibit the nice difference betwixt the muscular perfection of the former, correctly acquired by long habit; and the clumsiness of the latter, totally unaccustomed to the practice.

A daily pedestrian will walk forty miles with ease; while an indolent man, unused to travel, will sink with fatigue after half the journey. Practice with the dumb-bells, exercises the muscles of the arms, and renders them powerful; and to increase the power of the muscles of the lower extremities, young ladies with equal propriety should practise the skipping-rope.

A stout peasant, accustomed to delve with a spade, can easily do twice the work with it unfatigued, that a tailor, or a weaver, can perform with difficulty and pain.

Veteran soldiers, accustomed to endure fatigue, can march and countermarch during a campaign without very much lassitude and sickness; while raw recruits, unused to such laborious duty, fall down and die, or go to the hospital, after a few days' toil and travel.

The American Indians, the Caribs, and Australasian savages, accustomed to listen acutely to catch the distant sounds of the footsteps of wild animals and enemies, acquire so much control over the muscles of their ears, (which in Europeans are almost motionless for want of exercise,) that they can easily accommodate them, not only to their wants and wishes, but make them expand and contract mechanically with facility, so that they can distinguish the nicest sounds at long distances, which our unpractised and immovable ears could neither perceive nor command with acute listening and attention.

The muscles of the wings of birds, accustomed to long and rapid flight, are the most powerful parts of their bodies. The muscles of the legs and paws of tigers and lions are powerful, because they are not only employed in running, but in killing prey, which they frequently do with a single stroke. In short, no healthy man should complain of the want of sufficient muscular power; for if he daily employs his muscles as he ought, he will very soon acquire it. Every individual should exercise his muscles usefully. It was for this purpose alone that they were given him by his Creator; and any person who does not properly employ them, but lazily permits them to remain inactive, may as well be a polypus, a plant, or an automaton, and is very little better than a vegetable in human form; and fails to fulfil his high destiny with usefulness in the rational class of animal existences, among whom the Almighty has benevolently placed him. He who employs his muscles to destroy and injure his fellow-men, is an unnatural monstrosity—unparalleled in creation, except by the heroes and barbarians of his own species.

I will now proceed with the description of the muscles of the arm and other parts of the body.

There are nine muscles that move the humerus (or shoulder-bone): 1st. The pectoralis major is a large, thick, fleshy muscle, covering the whole of the breast. 2d. The latissimus dorsi is the broadest muscle of the back, and largest of the body: these two muscles form the arm-pit; the former pulls the arm forward, lays it upon the breast, and supports loads on the arm, as in carrying heavy baskets, &c., and also forms the anterior border of the arm-pit; the latter, when the arm is raised, brings it downward,

as we do in striking a blow with a hammer; or downward and backward, as when we knock with the elbow; or it rolls the arm inward and backward, as when we turn the palm of the hand behind our back. The edges of these two muscles receive the pressure of crutches in lame individuals: when both muscles act, the arm is pressed directly downward, as when we rise from a seat, or carry a bundle under the arm; and by their action we can raise ourselves over a beam by leaning on our hands. 3d. The deltoides is the first of those muscles which arise from the shoulder-blade, and are inserted into the shoulder-bone (or humerus); it is thick and fleshy, covers the top of the shoulder, and fills up the space betwixt the acromion and bone of the arm. It has three separate bundles of fibres, meeting about one-third way down the humerus, and forming a short, flat, strong tendon, which almost surrounds it. The guards in fencing are chiefly performed by the three bundles of fibres belonging to this muscle, and they are also the most powerful rotators of the arm. 4th. Coraco-brachialis arises from the coracoid process of the shoulder-blade, and is inserted by a short tendon into the os humeri (or arm-bone), nearly at its middle. Its action is to elevate the arm upward and forward, and to pull it towards the side of the body. It is therefore an imperfect rotator. 5th. Supra spinatus fills the hollow of the shoulder-blade above the spine, and is inserted into the upper part of the great tuberosity on the head of the shoulder-bone. Its action is to raise the arm directly upward, and, at the same time, elevate the capsule of the shoulder-joint. 6th. Infra spinatus is like the supra spinatus in every respect, and assists it in its action. 7th. Teres minor co-operates with the supra spinatus and infra spinatus, and assists them in raising the arm. 8th. Teres major is shaped like the teres minor, but thicker and longer, and lies a little lower down on the edge of the shoulder-blade. It performs the same kind of rotation of the arm as the latissimus dorsi, and draws the humerus backward and forward. 9th. Subscapularis lines all the cavity of the shoulder-blade, like a cushion, and assists the teres major and latissimus dorsi: it pulls the arm backward and downward, raises the capsule, and strengthens the joint. Those muscles which are implanted above the head of the shoulder-bone, are designed to elevate the arm; and as the supra spinatus, infra spinatus, and teres minor, are implanted into the great tubercle of the humerus, they must therefore raise the arm when they are in action. The deltoides being implanted a little lower down than these, performs the same action and with greater power; but as the subscapularis is implanted into the opposite side, or lower part, of the head of the shoulder-bone, opposite the former muscles, it must draw the arm directly downward and backward. The pectoralis major, and coraco-brachialis, are implanted into the outer edge of the bicipital groove of the humerus, in one direction, and pull the arm inward, and towards the side, and forward. But as the latissimus dorsi and teres major are inserted into the inside, (or lower part of the same groove,) they pull the arm directly backward, and roll the palm inward and backward. The shoulder-joint receives greater strength from its numerous muscles than its ligaments. The former are contractile, firm, and enduring; the latter, elastic, yielding, and apt to rupture.

There are two flexor muscles for bending the fore-arm. 1st. The biceps brachii flexor; and, 2d. The brachialis internus. There are also two extensor muscles that stretch the fore-arm. 1st. The triceps extensor; and, 2d. The anconæus. The uses of these four muscles are simply flexion and extension of the fore-arm.

There are thirty-one muscles situated on the fore-arm, for moving the radius (or its largest bone), the carpus (or wrist), and the fingers. These muscles perform supination, pronation, flexion, and extension. When we turn the palm of the hand down, it is called pronation; when we turn it upward, it is called supination. These motions are performed by rolling the radius (or large bone) on the ulna (or small bone) of the fore-arm. In these thirty-one muscles there are twelve flexors (or benders), arising from the inner condyle (or knob) of the humerus; and nine extensors (or stretchers), arising from the outer condyle of the same bone; and ten other muscles, varied in action, seated in the hand. 1st. The twelve flexors are named as follows:—1. Supinator radii longus. 2. Supinator brevis. 3. Pronator teres radii. 4. Pronator quadratus. 5. Palmaris longus. 6. Palmaris brevis. 7. Flexor carpi radialis. 8. Flexor carpi ulnaris. 9. Flexor digitorum sublimis. 10. Flexor digitorum profundus. 11. Lumbricalis. 12. Flexor longus pollicis.—2d. The nine extensors are also named:—1. Extensor carpi radialis longior. 2. Extensor carpi radialis brevior. 3. Extensor carpi ulnaris. 4. Extensor digitorum communis. 5. Extensor minimi digiti. 6. Extensor primus pollicis. 7. Extensor secundus pollicis. 8. Extensor tertius pollicis. 9. Indicator.—3d. The other ten muscles, varied in action, and seated in the hand, are called:— 1. Abductor pollicis. 2. Opponens pollicis. 3. Flexor brevis pollicis. 4. Adductor pollicis. 5. Abductor minimi digiti. 6. Flexor parvus minimi digiti. 7. Adductor minimi digiti. 8. Abductor indicis. 9. Interossei interni. 10. Interossei externi. These are all the muscles that belong to the upper extremity, and perform the motions of the fore-arm and hand.

The human hand is the most beautiful and perfect piece of mechanism in nature, and in its fingers are seated the organs of touch. Every motion that the genius of mechanics has discovered, simple and complicated, is perfectly exhibited in the human hand. All the movements of the gigantic machinery of steam engines, weaving, spinning, and tambouring factories, and of all other descriptions of machinery that have hitherto wrought, and are still working, for the benefit of man, are at best but noisy, clumsy, and bungling executions, compared with the still, easy, and graceful motions of the human hand. Its muscles are so nicely arranged, individualized, and combined, that there is nothing too difficult for it to execute, nor too simple to perform. It is the faithful servant and executor of the brain, and readily accomplishes, with the most facile fidelity, whatever it commands. Everything that human ingenuity has invented and physically executed, from the lifting of a blade of grass to the removal of a mountain; from the making of the smallest pin to the building of a palace; from the mutilation of a fly to the destruction of an army, have all been done by the human hand. Arts and sciences would have remained in original obscurity, sculpture, painting, architecture, machinery, and every illustration in experimental philosophy would have been for ever unexhibited, without the aid of the unwearied hand. It is the hand that elevates man in strength above the lower creation; and by its extraordinary power makes him the terrestrial lord of all. For want of hands, inferior animals fly before the hand of man. Any man who understands mechanics, and examines the mechanism of his own hand, with its sense of touch, bones, muscles, ligaments, blood-vessels, nerves, fingers, and thumb, divided into small joints, all acting in unity, combination, and harmony; and as a means to an end, accomplishing every purpose of the mind with ease, power, and dignity; will confess that chance could never have stumbled on such a perfect piece of mechanism without previous design and innate knowledge of the laws of mechanics; and with his mind soaring above the limits of materialism, he will rationally acknowledge and worship a great First Cause, as the Infinite Inventor and Omnipotent Creator of the human hand, which nothing less than a God could have planned, and executed, and made to act with so much ease and simplicity, harmony and adaptation, usefulness and power. How happy for mankind if this powerful instrument were only applied to wise and useful purposes!

## GEOLOGY.

### CHAPTER VI.

#### VOLCANIC ROCKS.

In the last chapter we presented the reader with a tabular view of the stratified formations, and promised to treat of the igneous rocks in the present.

Volcanic rocks generally occur in shapeless masses, and are destitute of organic remains. In some parts of Europe, such as Sicily, the country round Naples, and Iceland, active volcanoes still exist, which in recent times have poured out vast quantities of lava, ashes, and other matter. On the other hand, we find in Auvergne, Velay, and Vivavais, towards the centre and south of France, several hundreds of conical hills with craters near their summits.

These hills are composed of materials similar to those of active volcanoes; and, as mentioned by Mr. Lyell, " Streams of lava

may sometimes be traced proceeding from the cones into the adjoining valleys, where they choke up the ancient channels of rivers in the same manner as some of the modern lavas in Iceland have been known to do, the rivers either flowing beneath, or cutting out a passage on one side of the lava. Although none of these French volcanoes have been in activity within the period of history or tradition, their forms are very perfect. Some, however, have been compared to the mere skeletons of volcanoes, the rains and torrents having washed down their sides, and removed all the loose sand and scoriæ, leaving only the harder and more solid materials. By this erosion, and by earthquakes, their internal structure has occasionally been laid open to view, in fissures and ravines; and we there behold not only many successive beds and masses of porous lava, sand, and scoriæ, but also perpendicular walls, or *dykes*, as they are called, of volcanic rocks cutting through the other materials. Such dykes are also observed in Vesuvius, Etna, and other volcanoes. They have been formed by the pouring of melted matter, whether from below or above, into open fissures, and they commonly traverse deposits of volcanic tuff, a substance produced by the showering down from the air or incumbent waters of sand and cinders, shot up from the interior of the earth by the explosions of volcanic gases."

Extinct volcanoes, such as the above, occur in many other countries. Those of Europe are found in Catalonia, in the north of Spain, south of Sicily, Tuscany, the lower provinces of the Rhine, and in Hungary.

The volcanic rocks of Britain and Ireland, and other places in Europe, exist not in conical hills with craters, like the active and extinct volcanoes to which we have alluded; but many of them are strictly analogous to their composition, and their strata in their vicinity often intersected with volcanic dykes, similar to those which traverse the regions of active volcanoes. The absence of craters and conical formation in the older volcanic productions, is considered to be owing to their having been deposited under water; a circumstance, also, which accounts for their greater consolidation.

The term *trap* is generally applied to the older volcanic rocks, from *trappa*, a German word, signifying a stair. The reason of this appellation is, that many of these rocks occur in a terrace-like form: a configuration owing, in all probability, to the stoppage of large sheets of lava when flowing, whether at the bottom of the sea or on dry land; for we know that streams of lava generally terminate in abrupt precipices, similar to the beds constituting our trap ranges. The stair-like appearance may also, in some instances, be the effect of denudation; but the former cause seems best to explain the peculiar conformation of such ranges as are met with in the west of Scotland and other places.

Rocks of the description we are treating of are easily distinguished, even at a distance, from those of the stratified formations, occurring, as they do, in shapeless masses, and forming hilly tracts of great irregularity of surface, or in the form of walls or dykes penetrating other rocks, which they alter in character to a certain degree at the point of contact. There is a variety called basalt, which sometimes shows itself in columns, often of great regularity and beauty, as in the case of the Giant's Causeway in the north of Ireland, and the Isle of Staffa, and many other places.

Trap rocks often appear in the form of balls of various sizes, consisting of concentric coatings. The causes of these peculiar forms will be treated of afterwards.

In their internal structure, volcanic rocks are either hornblendic or felspathic (1), or are intimate admixtures of these minerals and others allied to them; quartz and mica rarely enter ing into their composition, as in the case of the granite rocks. The ingredients of mica and quartz, however, are abundant.

To the former of these groups, namely, the hornblendic, belong basalt, greenstone, syenite, &c.; to the latter, claystone, trachyte, clinkstone, compact felspar, porphyry, amygdaloid, scoriæ, and pumice.

As these are the more prominent of the igneous rocks, a short description of them, and their varieties and constituent minerals, may be necessary to enable the reader to distinguish them readily.

Basalt is of a black or bluish grey colour. It is commonly fine grained, and consists of an intimate admixture of felspar and augite, a variety of hornblende, with some oxide of iron: it frequently contains also crystals of a greenish-coloured mineral called olivine. The iron in hornblende is often magnetic, and accompanied by the metal titanium. The felspar is seldom discernible, augite being the predominant mineral. The affinity of augite and hornblende has been shown by the experiments of Gustavus Rose, who fused a mass of the latter mineral in a porcelain furnace, and found that it did not, on cooling, assume its previous shape or crystal, but invariably that of augite.

According to Berzelius, augites are composed of one equivalent of the bisilicate of lime, united with one equivalent of the bisilicate of magnesia. In an analysis by Rose, we have the following as the constituents of augite and hornblende:—

| Augite. | | Hornblende. | |
|---|---|---|---|
| Silica, . . | 53·36 | Silica, . . | 42· |
| Magnesia, . | 4·99 | Alumina, . | 12· |
| Lime, . . | 22·19 | Magnesia, . | 2·25. |
| Oxide of iron, | 10·75 | Lime, . . | 11· |
| Manganese, | ·67 | Potash, . | a trace. |
| | | Oxide of iron, | 30· |
| | | Manganese, . | ·25 |

The varieties of augite are, 1st, Diopside, which may be regarded as the type of the species. It is of a pale green or greyish white colour, and vitreous (glassy) lustre. Its hardness is 5·5, and its specific gravity 3·299. Before the blowpipe it melts into a semi-transparent colourless glass. According to Bonsdorf, this variety consists of

| | |
|---|---|
| Silica, . . . . | 54·83 |
| Lime, . . . . | 24·76 |
| Magnesia, . . . . | 18·55 |
| Protoxide of iron (2), . | ·99 |
| Alumina, . . . . | ·28 |
| Loss, . . . . | ·32 |
| | 99·73 |

2d. Herdenbergite is of a dark green colour, and sometimes nearly black. Its constituents are—

| | |
|---|---|
| Silica, . . . . . | 49·01 |
| Lime, . . . . . | 20·87 |
| Protoxide of iron, . . . | 26·08 |
| Protoxide of manganese with magnesia, | 2·98 |
| | 98·94 |

3d. Diallage is generally of a yellow bronze colour, clearer in the direction of the diagonal of the prism, and is of a mother-of-pearl lustre. A variety analyzed by Kohler, consisted of

| | |
|---|---|
| Silica, . . . | 53·20 |
| Lime, . . . | 19·08 |
| Magnesia, . . . | 14·91 |
| Protoxide of iron, | 8·67 |
| Protoxide of manganese, | ·38 |
| Alumina, . . . | 2·47 |
| Water, . . . | 1·77 |
| | 100·48 |

4th. Hypersthene has much the same appearance and character as diallage. Diallage on a matrass decrepitates (3), becomes of lighter colour, and gives off a little water. On charcoal, it is with difficulty melted on the edges into a green scoria. With borax, it is fused with difficulty into a clear glass, somewhat coloured by the oxide of iron.

Hypersthene, on the contrary, when heated alone in the matrass decrepitates slightly, gives out a little water, but does not change its appearance, while on charcoal it readily forms a green opaque glass, as is also the case when heated with borax. Its constituents are—

| | |
|---|---|
| Silica, . . . | 54·25 |
| Alumina, . . . | 2·25 |
| Magnesia, . . . | 14· |
| Lime, . . . | 1·5 |
| Oxide of iron, . . | 24·5 |
| Manganese, . . | a trace. |
| Water, . . . | 1· |

The other augitic minerals are sahlite, basaltic augite, Rothbraunsteinerz, acmite, bronzite, uralite, tremolite, antophyllite, Strahlstein, and basaltic hornblende. For the chemical formula of which, see Penny Cyclopedia, Vol. III. page 86.

From the statements made, it appears that the augitic and hornblendic minerals contain about 50 per cent. of silica, and that the remainder is chiefly composed of lime, magnesia, and

oxide of iron. The greatest per centage of alumina occurs in the hornblendes, these containing 12 per cent.

The singular columnar arrangement which basalt sometimes assumes, is not confined to the trap rocks in which augite or hornblende predominates: we meet with it in clinkstone, trachyte and other felspathic rocks; but in them it is seldom, if ever, so distinct and regular in its structure. Basaltic columns have commonly five, six, or seven sides, sometimes more or less. They are often divided transversely and nearly at equal distances. They vary exceedingly in length and thickness. M'Culloch mentions some in Skye 400 feet long. They occur in vertical, diagonal, curved, and horizontal positions.

The columnar structure has been found, by some very interesting experiments made by Mr Gregory Watt, to have originated from the manner in which refrigeration(4) of the mass took place. That gentleman melted seven hundred weight of basalt, and kept it in a furnace for eight days; "after the fire was reduced, it fused into a dark coloured vitreous mass, with less heat than was necessary to melt pig iron. As the mass cooled, it changed into a stony substance and globules appeared, then enlarged till they pressed laterally against each other, and became converted into polygonal prisms,(5) like those which constitute basaltic columns, showing that the orbiculated structure and regular forms of basaltic columns have resulted from the crystalline arrangement of the particles when in the act of cooling; and that the concavities or sockets have been formed by one set of prisms pressing upon others, and occasioning the upper spheres to sink into those beneath."

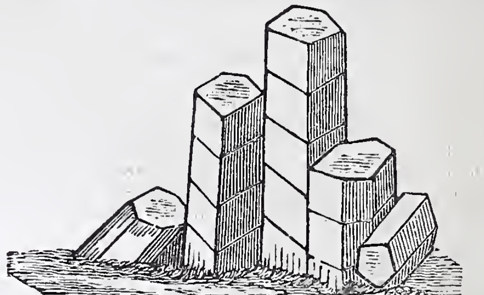
Many of the western islands of Scotland are wholly or almost wholly composed of basalt. Among these, however, Staffa stands pre-eminent. "The island is a complete mass of basalt: it is about two miles in circumference, and is surrounded by every side by steep cliffs, about seventy feet high, formed of clusters of angular columns, possessing from five to six or seven sides each. Fingal's cave, first made known to the world by Sir Joseph Banks, in 1774, is in the south-east corner of the island, and presents a magnificent chasm, 42 feet wide, and 227 in length. The roof, which is 100 feet high at the entrance, gradually diminishes to 50, and is composed of the projecting extremities of basaltic pillars, and the base of a causeway of the same materials. The vaulted arch presents a singularly rich and varied effect: in some places it is composed of the ends of portions of basaltic pillars resembling a marble pavement; in others, of the rough surface of the naked rocks; while in many stalactites mingle with the pillars of the recess, and add by the contrast of their colours to the pictorial effect, which is still farther heightened by the ever-varying light thrown from the surface of the water which fills the bottom of the cave. The depth of the water is nine feet. A boat can therefore reach the extremity of the cave in calm weather, but when the boisterous waves of our northern clime drive into the cavern, the agitated waves dashing and breaking among the rocky sides, and their roar echoed with increased power from the roof, it presents to the eye and the ear such a scene of grandeur as bids defiance to any description."—(*Wonders of Geology.*)

The Giant's Causeway, in Antrim, consists of hundreds of thousands of pentagonal(6) and hexagonal(7) columns, varying from one to five feet in thickness, and from twenty to two hundred feet in height. The district in which this remarkable trap formation occurs lies on both sides of the river Bann, and comprehends an area of 800 square miles. "The surface rises gradually on each side of the river to a considerable height, when it breaks into precipitous escarpments sloping abruptly to the primitive district of Londonderry, and overhanging the coast on the east and north in a series of striking elevations commencing near Belfast, and terminating west of the mouth of the Bann. Throughout this area the basalt is found coping all the eminences, and constituting an overlying bed of igneous rocks at least 500 feet in thickness.

The formations underlying the basalt are indurated chalk rocks,—the white limestone of Antrim succeeded by green sandstone reposing on blue argillaceous limestone, which again rests on red sandstone belonging to the coal formation, which appears to imbody the greater part of the basaltic tract. The rocks underlying the trap and basalt of this district, abound with evidences of the igneous origin of the former, old red sandstone being converted into hornstone, clay-slate into flinty-slate, coal into cinders, and chalk in many instances into granular marble.

The following section of the cliff of Bangor Head is from the Penny Cyclopedia.

| | Feet. |
|---|---|
| 1. Basalt, rudely columnar, | 60 |
| 2. Red ochre or bole, | 9 |
| 3. Basalt, irregularly prismatic, | 60 |
| 4. Coarsely columnar basalt, | 7 |
| 7. Columnar basalt, the upper range of pillars at Bangor Head, | 54 |
| 8. Irregular prismatic basalt. In this bed the wacke and wood-coal of Port Noffer are situated, | 54 |
| 9. Columnar basalt, the stratum which forms the Causeway by its intersection with the plane of the sea, | 44 |
| 10. Bole or red ochre, | 22 |
| 11, 12, 13, Tabular basalt, divided by seams of bole, | 80 |
| 14, 15, 16. Tabular basalt, occasionally containing Zoolite. | 80 |



The greatest mass of basalt, yet known, occurs in the province of Deccan in India, where it constitutes the surface over an area of many thousand square miles. In the whole of this extensive tract there is no trace of any volcanic crater; but as there are many dykes, it is inferred that the matter rose in a liquid state through cracks or fissures to the surface, and spread itself over the adjacent rocks. The same observation is equally applicable to other basaltic districts.

Greenstone is the term applied to that variety of trap in which grains of felspar are associated in a distinct manner with hornblende. The felspar is generally white, sometimes greenish or reddish. It often occurs in the same quarry with basalt, and is frequently of a rude columnar form. The dykes which traverse the coal fields of Scotland are principally of greenstone, as are many of the trap hills of that and other countries. When the felspar is of a red colour, the rock is denominated sienitic greenstone.

Clinkstone, or phonolite, is a greenish or greyish rock having a tendency to split into slabs and columns. It is hard, with a clean fracture, and rings when struck with the hammer,—hence the name. It is chiefly composed of felspar, but varies in composition. Compact felspar called also petrosilex and hornstone, is allied to clinkstone, but is more compact and translucent. It abounds in the upper and middle wards of Lanarkshire: cornean is one of its varieties. Claystone is an indurated clay usually of a purplish colour, and generally contains crystals of felspar, and sometimes quartz.

Amygdaloid is commonly of a porous or cellular structure, with many of the cavities filled with some mineral, such as calcareous spar, agate, or zeolite. The origin of this structure, says Mr Lyell, cannot be doubted; for we may trace the process of its formation in modern lavas. Small pores or cells are caused by bubbles of steam or gas confined in the melted matter. After, or during consolidation, these empty spaces are gradually filled up by matter separating from the mass, or infiltrated by water permeating through the rock. As these bubbles have been sometimes lengthened by the flow of the lava before it is finally cooled, the contents of such cavities have the form of almonds,—hence the name, from *amygdala*, an almond.

Trachyte is chiefly composed of glassy felspar with crystals of the same; it is usually white or greyish. Some of the varieties contain crystals of quartz. The name is derived from *trachis*, rough,—the stone having a roughness to the touch.

Porphyry is a trap in which crystals of felspar are irregularly scattered. If the base be greenstone, it is termed porphyritic greenstone; if basalt, porphyritic basalt, &c.

Tuff consists of small angular fragments of scoriæ, pumice, or other volcanic dust and ashes which fall in showers from the craters of volcanoes. When cemented together by argillaceous matter, they form a beautiful stone, which admits of a fine polish.

Scoriæ is a volcanic slag or cinder.

Pumice, a light spongy form of trachyte, formed from the froth of lava.

The other volcanic rocks are obsidian, or volcanic glass, a substance not unlike black bottle glass.

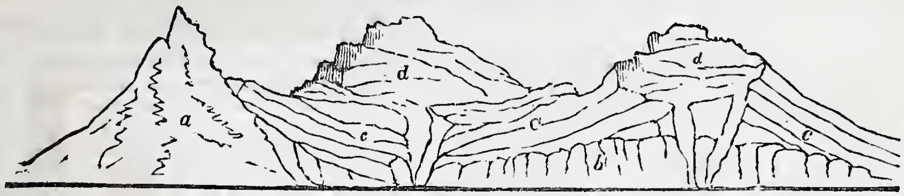
Pitchstone, another glassy variety of lava, black or greenish, and sometimes of a porphyritic structure.

Serpentine, a greenish variegated rock, capable of a fine polish, and containing much magnesia. It sometimes occurs in dykes, as is the case also with pitchstone.

The history of active volcanoes will form the next article.

☞ (1) Containing or consisting principally of felspar. (2) Iron in its lowest state of oxidation. (3) Crackles on the fire. (4) Cooling down. (5) Many angled. (6) Five-sided. (7) Six-sided.

*The following diagram will illustrate the mode in which the igneous rocks occur:—*




*a* may be taken to represent a granitic mountain axis protruding through the strata which flank it. These strata are shown on the right, and their positions indicate that the primary rocks have been disruptured and displaced by it; whereas the secondary strata *c* have been deposited since its elevation. *b* represents columnar basalt, and *d* overlaying masses of that rock, which have been ejected from beneath through the stratified formations *c c c*.

## BIOGRAPHY.

### JOHN BOYDELL.

John Boydell, called "the Father of the Arts in Great Britain," was born on the 19th of January, 1719, at Dorrington, in Shropshire; of which place his grandfather had been vicar. Engaged himself in the profession of land-surveying, it is said that his father intended him for the same line; but, fortunately for the community, not less than his son, accident threw in the way of the latter, whilst he was yet young, Baddesley's Views of different Country Seats, amongst which was one of Hawarden Castle, Flintshire, and which, situated in the parish of which his father was an inhabitant, first attracted his attention. Viewing it as an engraving, and judging that from the same copper an almost indefinite number of impressions might be taken, young Boydell resolved to relinquish the pen for the graver, as an instrument more worthy of his powers; and more likely to reward, as well as extend, the fame of his labours. Whether genius be, as a great moralist is of opinion that it is, "a mind with strong powers accidentally directed to some particular object," it appears most certain that this rising genius was induced to acquire the art of engraving from accidentally contemplating the misrepresentation of a mis-shapen Gothic castle.*

Enamoured with this "coarse print," young Boydell walked up to London, where, having found out its "coarse artist," Toms, he, at the age of twenty-one, bound himself an apprentice to him for seven years! Notwithstanding that he was now of age, his conduct, during his apprenticeship, is known to have been most assiduous. Whilst his companion, Chatelaine, who in the same workshop was etching and engraving at one shilling an hour, frequently would ask for his sixpence at the end of the first half-hour, and retire to an alehouse to expend it; Boydell, eager to attain all possible knowledge of an art on which his mind was bent, and of everything that might be useful to him, pursued his course with indefatigable zeal. Besides attending at an academy in St Martin's Lane to perfect himself in drawing, and otherwise giving himself to the study of perspective, he attempted the learning of the French tongue without the aid of a master, and acquired its pronunciation by resorting to the French chapel.

Having thus prosecuted his professional studies for six years, and finding himself to be a better artist than his teacher, he bought the last year of his apprenticeship from Mr. Toms, and became his own master. He now decided his condition for life. Returning to his native village, he married an amiable female, the object of his early love, with whom he lived for many years in great felicity.

Matrimony quickened his accustomed industry. Amidst the scenes of his youth, he sketched drawings of several romantic spots and remarkable buildings, which he subsequently engraved. Amongst those, were the Straits in Dovedale; Matlock-baths, and Cromford; Beeston castle, Chester castle, Conway castle, and Denbigh castle.

Unpropitious as the country at this time was to English artists, Boydell, returning to the metropolis, began to work for himself, and became a printseller of some eminence. The arts were now at a low ebb; whence, seeing with concern the immense sums drawn from his country by foreign artists, he, with that patriotism characteristic of him, resolved to endeavour to turn the stream of opinion to native talent; which, by his industry and perseverance, he ultimately did. His first attempt in this way, entitled the *Bridge-Book*, appeared in the year 1745; it contained six small-sized landscapes, designed and engraved by himself, moderately charged; and its success at once encouraged and empowered him to proceed with vigour in his course. The paper and printing would now cost more, however, than the sum at which his book was then sold. He continued to employ himself in designing and engraving many views of places in and near London, which were generally published, as his landscapes had been, at the price of one shilling each. Besides these efforts, he copied prints from Vandevelde, Brooking, Berghem, Ostade, Castiglione, and Salvator Rosa. Nor did he once abandon the hope of fame. Even at this period he was so much alive to honourable reputation in the arts, that, after consuming several months in copying an historical picture of Coriolanus, by Sebastian Concha, he so much disliked his own performance as to cut the plate to pieces.

The facility with which he drew, etched, and managed the dry needle, enabled Mr Boydell to finish no inconsiderable number of prints. Reviewing the numerical amount of these prints—which were drawn and engraved when he had much other business on hand—they attest his uncommon industry; whilst the manner in which many of them are executed—instance the Medea and Jason, from Salvator Rosa—evinces talents which practice, with his constitutional perseverance, would have rendered highly respectable. Toward the close of his life, the artist collected the whole of them into one port-folio, with a view of showing the great improvement of the art since the time of their publication. It is published at five guineas; and is thus spoken of by himself, in his introduction to it. "To the lovers of the fine arts, it may," remarks Alderman Boydell, "be an object of some curiosity, as it was from the profits of these Prints that the engraver of them was first enabled to hold out encouragement to young artists in this line; and thereby, he flatters himself, has somewhat contributed to bring the art of engraving in England

* "After his oracle, Dr. Johnson," says Mr. Gibbon, "my friend Sir Joshua Reynolds denies all *original genius*, any natural propensity of the mind to one art or science rather than another. Without engaging in a metaphysical, or rather a verbal dispute, *I know*, by experience, *that from my early youth I aspired to the character of an Historian.*"

to such a state of superiority. It may likewise be added," continues the alderman, "that this is the first book that ever made a Lord Mayor of London. Few men have had the happiness of seeing, in a single lifetime, such a rapid improvement; and the publisher will be gratified, if, in the future history of the art, his very extensive undertakings shall be thought to have contributed to it. When the smallness of this work is compared with what has followed, he hopes it will impress all young artists with the truth of what he has already held out to them—that industry, patience, and perseverance, united to talents, are certain to surmount all difficulties."

Now that the taste for prints began rapidly to extend, Boydell, having felt how sensibly his own interest suffered, together with the honour of his country, by the sums annually drawn from hence in return for the productions of French artists, began to look out for some English engraver who should equal, perhaps excel, them; and, in Woollett, he found one. Woollett's talents were first employed on the temple of Apollo from Claude, and two Premium Pictures by the Smiths of Chichester; but the Niobe and the Phaeton, from Wilson, published by subscription, at five shillings each, in 1761, formed the pillars on which Woollett's reputation was to rest; and proved such a specimen of the English School, as fixed the admiration of Europe.* Fifty guineas was the sum stipulated for the engraving of the first of them, though one hundred was the amount given. Another fifty guineas was also the price conditioned for the second, but the artist ultimately received one hundred and twenty. Several proof prints have since been bought, in public auctions, at ten pounds each; and, at Mr Hilliard's sale, one of them fetched eleven guineas! "Niobe," observes an amateur, "bears a very high price, and deservedly so: the whole number worked off from this print, is, perhaps, a secret of trade; but it certainly was not less than 7000 or 8000." This was a prodigious impression in those days. Indeed, as it has been justly said, the number of fine, of inimitably fine, prints, which have since that time been engraved in this kingdom, have not only furnished an important as well as interesting branch of commerce to us, by turning the balance of this traffic immensely in our favour, but have indisputably fixed the English School above every other in Europe!

Persevering in the course which he had so singularly and successfully chosen, Boydell now attempted that undertaking, the salutary effects of which have proved incalculably great, and which exhibited to an astonished and delighted age—the Shakspeare Gallery. What with his engraving of prints at an unusual expense, and his labouring to establish this first British School of Historical Painting, he expended something more than three hundred and fifty thousand pounds. The advantages thus obtained to the arts and artists were soon obviously seen: the Poets' Gallery, the Historic Gallery, and the British Gallery—originally the Shakspeare—owed their successive rise, and the splendid works which issued through them into the world, to the example of him who has, by way of distinction, been denominated the Father of the Arts.

Nor were his fellow-citizens unmindful of his worth. He was chosen Alderman of Cheap Ward, in 1782; he served the office of Sheriff in 1785; and he was elevated, in 1790, by the warm and united suffrages of the Livery of London, to the first honours of their City. In the council-chamber of Guildhall are displayed both his patriotism and his ardour for the advancement of the arts. He presented to the corporation of the city of London several highly valued pictures: some of which are battle-scenes; whilst some, on the other hand, are designed to impress on the minds of the rising generation the sentiments of virtue, industry, and prudence, in various well-imagined allegorical representations, painted by Rigaud, Smirke, Westall, and others.

Reflecting on the exertions of Alderman Boydell, one cannot but regret that the property which he had so deservedly acquired was subject to its reverses. Owing to the French Revolution, however, and the consequent War, he experienced such losses as necessitated him to obtain from Parliament an act for disposing of the Shakspeare Gallery, and his Pictures and Prints, by way of lottery. He lived to see every ticket disposed of, but died before the lottery was drawn. He departed this life on the 12th of December, 1804, in the eighty-fifth year of his age.

Alderman Boydell was exemplarily attentive to the duties of his office; and very often, when he was not in rotation, supplied the place of the sitting alderman. Considering the incessant attention which his own concerns required of him, this was, indeed, "no slight trouble; but he was enabled to do it from having generally arranged his business so as to be before-hand with the duties of the occasion. His character," therefore, was evidently "opposite to that of the Duke of Newcastle; of whom George the Second once said, that—He lost an hour every morning, and was running after it all the rest of the day!"

Indefatigability is requisite to successfulness. Alderman Boydell has shown, for the benefit of youth, should they desire to pursue his steps, "that industry, patience, and perseverance, united to talents," and joined with conduct, are, humanly speaking, "certain to surmount all difficulties" or impediments.

Invincible determination seems to have been one of his constitutional qualities. Having once formed the resolution to become an engraver, nothing could divert him from pursuing this design. Few young men, when but twenty-one years old, could, like him, have cheerfully embraced six years of the servitude called apprenticeship; steadily adhering to a plan of action, so long to come. Our young adventurer saw this, however, when he determined his course. Even his love was subservient to this great object. Boydell did not marry, though early attached to her who afterwards became his wife,† till he had succeeded in compassing the art of engraving.

His personal character has been thus drawn by one who had familiarly observed him:—Viewed as a magistrate, the city, in whose government he bore so considerable a share, experienced and acknowledged the benefit derived from the assiduous and upright discharge of his public duties. When he was elevated, by the warm and united suffrages of the Livery of London, to the first honours of the first City in the World, the most sanguino expectations awaited the year of his administration; and those anticipations were more than satisfied. Ever attentive to the interests and wishes of his fellow-citizens of all descriptions,—assiduous in the discharge of every duty, always aiming to be just,

* William Woollet owes his reputation to his talents alone. He was born at Maidstone in Kent, in August, 1735. When he first went to London, his abilities seem not to have been particularly remarkable; but having been placed under Tinney, then an engraver of some eminence, be very early distinguished himself; and his "Garden Views," executed whilst an apprentice, have considerable merit. Although still a young man, he was employed by Boydell (Alderman and Print-Dealer,) to engrave the *Niobe* from Wilson's celebrated picture; and though the sum for which this was executed, must, even in his days, have been most inadequate to the labour and science required, yet the masterly manner in which the engraving was finished at once established his fame, and evinced the increasing superiority of his talents. This estimable print bears a high price, and deservedly so; for as a representation of a land storm, if not absolutely unrivalled, it certainly ranks with the very finest. In storms, indeed, Woolett was superior to Vivares. After a great display of abilities in landscape, be undertook to engrave history; and his first plate was the *Death of General Wolfe*, from West's painting. This fine subject was received with general admiration; and if his merits had neededadditional testimony, they now obtained it by his appointment to the honourable situation of Engraver to the King. He next exhibited his great talents in portrait-engraving; and in that line executed a much-admired likeness of *Rubens*, from a picture by Rubens himself. Even animals were engraved by him with equal truth and closeness to nature; of which the *Pointer* from Stubbs is a memorable example. But of all his works, perhaps, that which has obtained the highest professional approbation is *The Fishery*, in which a ship-of-war is represented as coming into port in a heavy gale of wind. This bears a greater price than either the Niobe or the Death of Wolfe; and is unquestionably, both in point of execution and drawing, one of the first productions of the *burin* that has ever appeared.

Woollett was cut off prematurely, yet not till he had exhibited a vigiour of taste, a depth of judgment, and a power of handling, fully equal, if not superior, to any engraver that ever flourished. His whole soul seemed to be absorbed in his profession; his mind was perpetually occupied in endeavouring to extend the bounds and capabilities of his art; and some laughable anecdotes have been circulated of his remarkable absence, though in the midst of company. His knowledge of drawing was more than extensive; it was complete. From his early years, he employed every opportunity to improve himself in it; and it has been told as a fact, that when journeying by the stage-coach to Maidstone, he prevailed on the coachman to stop till he had sketched a very fine dock which be saw growing by the road-side.

His death was what is usually called accidental; be ruptured his groin in crossing a style; and his delicacy preventing him from getting proper assistance in sufficient time, be died, within a few months, in extreme agony, May the 23d, 1785, in his fiftieth year. Four days afterwards, his mortal remains were buried in St. Pancras churchyard, where an upright grave-stone records his memory; but a more noble monument to his genius has been erected in the cloisters of Westminster Abbey, from the classic chisel of Banks. This is a moral cenotaph: its general design is a votive altar, crowned by the bust of Woollett, finely executed, and having in front a bas relief—representing "The genius of Engraving handing down to posterity the Works of Painting, Sculpture, and Architecture: whilst Fame is distributing them over the Quarters of the Globe." Sherwin has finely engraved the portrait of Woollett.

Woollett and Anthony Walker were fellow-pupils to Mr. Tinney. The inscription on the grave-stone of the former artist is—"William Woollett, Engraver to his Majesty, was born at Maidstone in Kent, upon the 15th of August, 1735, He died the 23d, and was interred in this place on the 28th day of May, 1785."

† Speaking of this event, the author of the *Public Characters* says, that "the first use made of his freedom," having left Mr. Toms, "was to return to his own country, where he married a very deserving young person to whom he had an early attachment, and with whom he lived many years in great felicity."

and ever inclining to be merciful; splendid as a magistrate, but humble as a man, he omitted nothing that belonged to his dignity; he forgot nothing that belonged to himself; and he thereby gave a distinction to the pretorian period which will be remembered as long as the public mind retains a proper sense of public virtue.*

But it would not be doing justice to this excellent man, if we did not add, that his private qualities accompanied the march of his public virtues. They were, indeed, almost peculiar to himself. In advanced age, he retained the unsuspecting confidence of early years, and the amiable simplicity of unexperienced life; nor, considering the long and continual dealings he had with different classes of men, can the inviolate possession of these qualities be reconciled to our understanding but by that love of doing right, and that dread of doing wrong—by that inflexible integrity, in short, with which he commenced, continued, and, at length, concluded his venerable life.

# HISTORY.

## CHAPTER IV.

### GEOGRAPHY.

The geography of every country is a part of its history. Geography means neither more nor less than the description of the earth, of the world we inhabit. The geography of any particular district is a description of its physical peculiarities, including an account of its superficies, as it is shared between land and water, hill and valley, lake, river, or sea. It includes its subterranean structure, and its subterranean and meteorological phenomena as far as we know. It includes its productions, spontaneous or artificial, animal, vegetable, or mineral. All these things are included in our conception of geography, or earth-description, and all of them, a little reflection will suffice to convince us, constitute an important part of a nation's history. The temperature of a country's climate influences strongly, not only the habits of men, but also their innate character and disposition. In cold climates, the necessity of warm clothing and the difficulty of procuring adequate food, it is easily seen, will produce more provident and active habits among the inhabitants. In warmer climes, we find a greater susceptibility among the inhabitants, a quickness of apprehension, and a greater delicacy of taste than we find among the inhabitants of colder regions. In natives of the north, on the other hand, we find a greater steadiness of purpose, greater powers of previous calculation and arrangement, and a more solid and firmer texture in their mental capacity. The necessity of our nature that we should earn our bread in the sweat of our brow, will, under these circumstances, lead men in different localities into widely differing spheres of activity, calculated to develop in differing and unequal degrees, the dispositions and faculties of his nature.

Again, the changes which through the succession of periods of time, take place in the geographical condition of a country, will exert an influence in modifying or changing the habits and dispositions of its inhabitants, which it is important the historian should be cognizant of. It is impossible minutely to analyze these changes. For the purpose of the historian, however, it is not sufficient that he possess this knowledge with reference to one determinate period of time merely. There are circumstances, which render it necessary that he should possess such statistical details regarding the country inhabited by those whose history he is tracing, if not of every moment in their history, at least of such stated intervals as are nearly enough approached to each other, to enable us to assume, that little change took place during the intermediate time. These circumstances are changes which may take place in the features of a country. A country may be stripped of its trees, and thus its climate altered. The sea may have receded from, or encroached upon, its shores—mineral treasures may have been discovered, or the art of making them available may have been lost. There are many other changes, that may from time to time produce alterations in the geography of a country, calculated to produce changes in the condition and character of the inhabitants; and the knowledge of them is therefore indispensable to the historian, if he would bring his investigations to accurate conclusions.

On casting our eyes backward, we find very inadequate notions of the sphere and objects of geography entertained at various times, in various countries. Few of the express treatises on the subject are to be found sufficiently expansive for the purposes of the historian; and there are many periods, relative to which no such records exist. But it does not follow, that because such treatises do not exist, therefore geographical knowledge regarding these periods was and must remain a complete blank. The form of a science is an important, but not an indispensable part of it. There have been writers on detached portions of it, and of these the historian may avail himself, in the absence of systematic treatises, bearing upon particular periods of time. There is one thing, however, which must here be remarked: that although every age has not its geographical system—its classified compendium of geographical knowledge—every age has nevertheless its geographical theories. There is a propensity in the human mind which leads men, in the absence of ascertained facts, and for want of sufficient powers of correct induction, to build up hypotheses, in many cases the most baseless and extravagant. We find illustrations of this in the golden chain of Homer, by which the earth is suspended from heaven. We find it in the Indian belief, that the world is supported on the horn of a cow, that the cow stands on an elephant, the elephant on a tortoise, the tortoise on God knows what. We find it in the bigotry of the inquisitors who condemned Galileo to a dungeon, for maintaining that the earth moved.

Theories like this, giving a form to men's notions of the world they inhabit, have existed long anterior to systematic geography. The only way of ascertaining and estimating the amount of this biassing influence, in any individual case, is from the indications afforded incidentally by the author himself.

In reviewing the advance of geographical knowledge, there are three great periods, each of which will be most fittingly and advantageously examined apart. The first extends from the earliest periods of which any written records have been handed down to us, till the bestowing of a systematic form upon geographical science by the school of Alexandria; a sketch of the origin and fortunes of which has already been communicated. The second extends from the introduction of this more systematic method of treating the science, till the age of Columbus. The third relates to the progress of geographical science, down to the present day.

I. During the continuance of the first period, we are obliged to glean our geographical notices from works devoted to other topics. The termination of this period varies with different nations: it is determined necessarily, not by the date at which the more scientific form was given to the science at Alexandria, but by the date at which each nation in succession became acquainted with, and adopted it. Of all the nations which became ultimately incorporated in the Roman empire, and where scientific progress was ultimately influenced by the school of Alexandria, there are only three of which we possess records in their own language, previous to this date,—the Roman, the Grecian, and the Jewish. The Jewish, (that is their genuine writings in the classical Hebrew, or in that Chaldaising dialect which most nearly approximates to the classical Hebrew,) are all really prior to it. Of the Roman, we may almost predicate, that they are all in point of time posterior to it, but inasmuch as they are of a time, when the mere systematic views of Alexandria were altogether unknown, or only imperfectly understood, and consequently uninfluential at Rome, they nevertheless belong essentially to this more early period. A large proportion of Greek literature, containing by far its most original and valuable writings, belongs more generally to this era.

The peculiar characteristic of the geographical details, which may be gleaned from the Jewish writings, is a vivid and graphic reality, as long as the events of the narrative occur within a

* Estimating the character of Alderman Boydell as to these points, he is thus spoken of by another of his contemporaries. "Of his conduct as a citizen, it is not necessary for this page to record any eulogium. In the different offices of Alderman, Sheriff, and First Magistrate of the City of London, he acted in a manner that will be remembered by many gratefully; for though inflexibly just, he was ever merciful; and when husbands came before him, with complaints of their wives; masters, of their servants and apprentices; fathers, of their children; he invariably, and often successfully, tried to reconcile them to each other, and accommodate their differences."

limited sphere. The boundaries of this sphere are not very distinctly defined : they extend a parallel of latitude passing between Damascus and the termination of the chain of Mount Lebanon in the north, and a line between the bottom of the gulf of Akaba (the bifurcation of the Red Sea) and Cairo in the south : between the sea which washes the coast of Syria in the west, and the edge of the desert which lies between the fertile land to the east of Jordan and the Euphrates, in the east. The relative position of the most important places within these limits, is tolerably well ascertained; but their real distances from each other are rudely estimated as so many days' journey. The general character of the country—as level or hilly, coast or inland, sand-waste or marshy, is faithfully indicated ; but the extent, interruptions and intersections of mountain ranges, are nowhere noted in detail. Some of the most striking meteorological phenomena are correctly given ; natural history as far as it relates to the vegetable and animal kingdom is deficient, and in regard to the mineral kingdom still more so. The incidental information furnished in these writings is that of writers intimately acquainted with the localities of the central point, and capital of their native land, Jerusalem. Every wider circle successively described around this point, is more and more vaguely known to them, and with regard to all beyond the limits at first pointed out, they are in utter ignorance. Their familiarity with the objects within the sphere of their acquaintance has a twofold effect. It enables them, in some instances, to delineate a bold and precise outline with one brief nervous expression ; in others, it leads them to rest contented with naming, what being familiar, they never dream can be unfamiliar to any other. Their incidental notices, available in natural history, occur almost exclusively in their poets ; are rather expressions of the impressions of external nature upon a passionate temperament, in a state of high excitement, than correct delineations of objects as they exist in themselves, and are therefore to be carefully and guardedly used.

The peculiar characteristics of the geographical details which may be gleaned from Greek authors of this era, are a wider range of the earth's surface to which they relate, frequently less accuracy, greater confusion, and difficulty of reconciling conflicting statements. The origin of the greater confusion is this :—The Jews were a very numerous tribe of the great and Semitic race, among whom a family unity of thought and expression was kept up by their exclusive religious opinions and ritual. The Greeks were a natural family—their language, customs, and laws throughout that extent of the earth's surface, over which they were scattered, were much the same. But they were not like the Jews—one organized body. They had not one temple to which all their eyes were incessantly turned. They had not a Levitical tribe dwelling among the others, without an exclusive local habitation of their own, to remind them incessantly of their brotherhood and unity. Every city in Greece almost governed itself. Hence, to give a simple example of the confusion necessarily introduced into geographical details by this circumstance—almost every city in Greece had its own peculiar standard of superficial measurement, and yet all these different standards have the same name derived from their common ancestors. The contradictory statements regarding the distance between places occasioned by this circumstance is the least evil arising from it: often when one author only specifies such a distance, we are unable even to conjecture the length to attribute to the term he uses. The more precise and artificial methods of computing distances in Greece, are often less available than the rude estimates of the Jews. Another source of perplexity lies herein, that much of the information contained in Greek writings, refers to lands foreign to the writers, and to periods which were ancient to them. The whole almost of what we find in the Jewish annals, relates to their own country—there is no foreign admixture there ; the narrative relates to scenes familiar to the writer. The more locomotive Greek rambles over a wider surface ; tells us of much with which he has become acquainted only by a single transient visit—he tells much of which he knows only from hearsay. Not only is his knowledge on this account more flimsy, inasmuch as it is less deeply graven, or not at all on his sensorium ; he is driven to add to the confusion we have already noticed, as existing in his measures of distance by borrowing the names of the measures of foreign nations, to express the distances between places in foreign lands. To compensate for this greater confusion and vagueness, we find towards the close of this era among Grecian authors, a scientific spirit growing up, which brings them back to accuracy, and communicates greater fulness of knowledge in other matters. The military precision of the movements of Xenophon and Alexander, the care with which they were recorded by men of scientific attainments, give a precision to the details of the close of the period superior to the Jewish. And the systematic inquiries of Aristotle into the natural history of animals and other departments of physical phenomena, furnish us with an amount of available information, of which any counterpart would be sought in vain in the Hebrew writings.

The geographical details to be gleaned from earlier Roman authors have also a peculiar character, springing from the very marked national character of that people. With the Romans everything relating to matters of admeasurement was business-like and practical. In a class of writings repulsive enough in their form, but valuable as containing information nowhere else to be found, and hitherto too much neglected, known by the designation of *agrimensores*, i. e. land-measurers, we find information respecting the accurate manner in which the Romans were in the habit of measuring the lands allotted to their soldiers or citizens in conquered territories. The mummery and superstitious observances prescribed to the measurer, the object of which however is clearly to ensure accuracy, lead us back to the old times when Rome along with augury learned its first useful arts from Etruria. We are thus furnished with the certainty that the Romans were from the earliest periods of their history, nicely accurate in their measurement of the earth's surface for domestic purposes. Let us next turn our attention to the development of their unrivalled system of tactics. Rome was to them but the central point from which all their excursions to plunder the surrounding world emanated. From the legendary conquest of the independent state of Fidenæ, some five miles distant from the independent state (or city, for the terms were then synonymous) of Rome, by Romulus, down to the annexation of the greater part of Britain to the Roman empire, every seizure of territory by the Romans was made after a careful calculation of the food requisite to maintain it, the means of support for that force, the amount of tribute over and above which could be exacted by the imperial city, without altogether rendering the inhabitants desperate, and the extent and facility or difficulty of transport on the roads leading to it. These calculations were made with the same precision and accuracy as in the measuring out of acres from the public lands to private citizens. In the castrametation of the Romans, the same addiction to accurate mensuration is visible. It is owing to this peculiarity of the Roman character, that wherever that nation sent its exploring bands, that is, wherever it projected or effected conquest, the notices contained in Roman writers of that territory furnish us with accurate notices of the distances between place and place,—the first great requisite of accurate geographical information. The manner in which this outline is occasionally filled up, is equally characteristic of the nation. It furnishes us with such notices of the face of the country and its meteorological phenomena as are calculated to be useful to any one about to conduct military operations in it, with such notices of its products as are interesting to him who may have an army to feed in it, with such estimates of its wealth as are alluring to freebooters on a large scale.

These hasty sketches may serve to guide to an approximate estimate of the value of the geographical information to be derived from each of these three classes of sources. In this period we are furnished only with materials. The geographical system must be constructed of them by our own exertions. It need scarcely be stated that in executing this task it will be necessary to keep steadily in mind the date of each work from which we extract information, seeing that in consequence of a nation alternately increasing by conquest from others, or being diminished by conquest from itself, the same name denotes at different periods very different extents of territory ; that in some instances where both influences have come into play, the same name may be found applied at one period to a totally different portion of the earth's surface from that to which it is applied at another. It is however necessary to keep steadily and anxiously in view, that the geographical statements of this period, although sometimes perverted by a preconceived cosmogony, are never rendered more accurate by correct notions of the real form of the earth ; that the immense majority of the writers and observers all proceed

upon the assumption that the earth was one great extended plane, and that hence innumerable errors occur in their statements regarding the relative positions of places and their bearings to each other, the figures of lines of coast, and the directions of mountain ranges. In attempting to reconcile their statements with ascertained facts, we must always keep steadily in view the point from which their observations commence, the line along which they are carried on, and the observer's preconceived notions of the figure of the earth's surface.

II. The second period of geographical science detailed, reached from the systematizing of geography by the Alexandrian school, down to the age in which, a new impetus being given to geographical discovery, the researches of Columbus and his successors struck out new fields of investigation.

Towards the close of last chapter, we had occasion to observe that the Alexandrian school had rendered more service by its preservation of the works of original authors, and by its patient perseverance in the accumulation of facts in physical science, than by awakening or training powerful and original minds. There are some poets appertaining to this great reunion of literary men whom we would be loath to lose, at the head of whom stands the ever fresh and graphic Theocritus; but omitting these as not bearing directly on our immediate purpose, all its greatest and most useful members may for the present be considered as belonging to one of two classes. The first of these was called into existence by the sedulous attention paid at Alexdria to the collection and preservation of the writings of the philosophers and poets of former times. The studies necessary for illustrating what time was rapidly rendering obscure in these writings, or for preparing new and more correct copies of them, produced a class of scholars to whom the epithet grammarians was applied. This epithet in its original acceptation indicated a familiarity with many branches of knowledge besides that to which it would now imply the restriction of a man's thoughts. Every thing that was necessary to the elucidation of the classic writers was included in it; and among these not the least important was an acquaintance with the geography of many countries. Greek and the Grecians occupied in Asia eastern Europe, and north Africa, in that age, a position not very dissimilar in matters of science and literature from what French and Frenchmen did in Europe during the greater part of last century. Alexandria was, in the century immediately preceding and succeeding our era, what Paris was from the time of Louis XIV. till the French Revolution. Alexandria was frequented by visitors from all parts of the then known world. Alexandrians visited all parts of the then known world, and there were indefatigable thinkers in Alexandria, who availed themselves of both these sources of information to extend their stores of knowledge. While by this means the grammarians were accumulating the *data*, the facts of geography; the other class to which we have alluded were preparing to revolutionize the outward form of the science, or more properly to elevate it for the first time to the dignity of a science.

The systematic geographical works which must be regarded as the nucleus of our knowledge during this period, belong to its earlier half. During the greater part of the second, men contented themselves with a fragmentary and second-hand knowledge of their contents. During the second they contented themselves with full and accurate acquaintance with the originals, without seeking to improve upon them. The most important of these systematic works are those of Pliny the elder, Strabo, and Ptolemy. From these writers we obtain not only rich and minute details of the geographical facts of their own time, but of the geographical theory which gave form and consistency to the science during the whole period of which I am now treating.

The works from which our supplementary knowledge is derived may be divided into two classes. The first are those compiled prior to the subversion of the Roman empire. These have all a kindred form and spirit; their writers are all more or less immediately trained in the doctrines of the Alexandrian school. With the irruption of the northern tribes, a new era of greater diversity commences. The ecclesiastical writers retain for a time the old impress, but it gradually wears off. The Jewish writers on geography retain it still longer; down to the thirteenth century we can trace Alexandrian learning in them. The Arabian writers are of the same school and time. Then comes the age of our Mandevilles, and Marco Polos, the credulous but graphic and inquisitive precursors of a better age.

In this period we have systematic writers who furnish us at once with a framework wherein to arrange whatever facts we can glean up, and a key to the right understanding of their language. We are less apt to be misled by dreams of cosmogony; for the human intellect is sufficiently advanced to allow even the minds most addicted to such mystical pursuits to recognise their limits, and avoid carrying them into the field of geography. Towards the close of the period the sources become both more numerous and varied; and a more extensive and careful study of national and individual character than before, is necessary to enable us to estimate the value of different pieces of information.

III. The revival of intellectual activity throughout Europe to which we adverted cursorily towards the close of our remarks on the second period of the history of geographical science, displayed itself with almost preternatural activity in that department of knowledge. The ancient classical authors were diligently studied and edited. Information was collected from merchants and mariners, Christians and Mahommedans, redacted and published. The art of map-making, pointed out by the Alexandrian school, and improved by the Arabs, was sedulously practised. Free states and monarchs vied with each other in patronizing ingenious and adventurous men, who roamed through unknown lands and penetrated into unheard-of seas. The fruits of this busy industry were huge accessions of wealth, and continual new gratifications for an imaginative curiosity, with which "increase of appetite did grow with what it fed on."

In the middle of this busy crowd arose a man unequalled before or since his time by cool intellectual daring. The shape of the earth had been accurately enough inferred before his time; but although the learned might yield a theoretical assent to the problem, even with them it could not supplant the impressions of the senses. Beyond the ocean which had been found to wash the shores of almost all the known world, all was dim conjecture To venture out into the unknown, a region over which all the darkest and most fantastic shadows of imagination hover, was an undertaking, at the bare conception of which, thought shuddered and recoiled. Yet one man was found with sufficient practical confidence in the inferences of science to adventure on a voyage, which however unexciting it may seem to us, who can converse every day with people returned from making it, must have been on the first outset second only in awful anxiety to the plunge into eternity. It was then as it were a launching out into infinite space. This dread task was undertaken by Christopher Columbus, who not only held the rudder of his bark as calmly on the mountain billows of the unknown unmeasured Atlantic, as on the sunny sea of his native Italy, but kept within bounds at the same time the dangerous convulsions of well-nigh frantic superstition and despair in his crew. The brilliant shores to which his course conducted him were an appropriate minor paradise—the reward of a true heroic though minor act of faith.

Almost contemporary with this great bound in geographical discovery, was that advance in physical science which has kept pace with it ever since. Each has played beautifully into the hands of the other. While Galileos, Newtons, and Laplaces have arisen in quick succession, Cooks, Bruces, and Humboldts, have been equally indefatigable in their sphere of action. In this wide vineyard the labourers have neither been few nor indolent. Not an instrument has science invented, not a new field of inquiry has she opened up, but travellers have immediately availed themselves of the one or the other. Arcs of the equator and meridian have been measured. The mysterious indications of the magnetic needle have been followed up, we have reason to believe, to the spot it points to. Commerce first sent her pioneers. To these have succeeded on a more high and holy mission, but not with stouter hearts, the emissaries of science and religion. No recorded time, any more than any given space, has escaped their curious research. While our Franklins and Parrys have been exploring the amorphous arctic regions, where man yet crawls about, leaving no enduring trace behind, our Riches, and Champollions, and Niebuhrs, have traversed the now deserted scenes of the early history of our race, to save from oblivion what yet remains of their handywork, and to piece out the too scanty fragments of those records which have reached us.

The works more or less scientific in their nature, from which a geographical knowledge of this period is to be gleaned, are so multitudinous as almost to defy classification. They are of very unequal value, but almost with every year we can trace an improvement in them in point of accurate habits of thinking. The number of travellers who submit their remarks to the public has increased, and will continue to increase. It was a noble project of Milton, in framing an ideal system of education for the commonwealth he fondly hoped to see established, to propose, that of that class to which even he in his age thought the advantages of systematic education must be confined, should travel, and on their return submit a report of observations during travel, to government, thus furnishing additions to the national stock of knowledge, and a test of their capacity for public employment. The increased power and importance of the general public, and the increased use of the press, is supplying on a much more extended and practical scale what Milton wished, rather than hoped for, on a much smaller. The number of our curious travellers far exceeds what he could have contemplated; the public is the acknowledged ruler in last resort; and the press is the means by which those who would serve this sovereign submit to his inspection their essays to instruct or amuse him, or it may be merely to show him how clever they are.

But if our sources of incidental and fragmentary geographical knowledge are accumulating and increasing in value, our systematic works in which they are made available, are yet to come. In this country we have not one worth naming. France has given us, in Malte Brun, only an approximation to what is required. In Germany several professors, scarcely known beyond their respective universities, have traced in lectures the plan upon which it must be effected. Humboldt in his travels has given a glorious but fragmentary example of what such a work would be if rightly accomplished. Perhaps the day is not yet come. But surely it cannot be far distant.

### LANGUAGE.

*Ce n'est que le premier pas qui coute,*—the whole difficulty lay in taking the first step, said the French lady when told that St Dennis had walked after his head was cut off. A similar observation has always occurred to us while reading the theories of Blair, Murray, and others, respecting the *invention* of language y man. They tell us that men agreed that one certain sound hould always be understood to indicate one certain idea, another another; and thus they go on, building up a language from its simplest and rudest elements to the highest grade of refinement. We do not see the possibility of making the first step. It is impossible to conceive men making any such agreements without the aid of language to enable them to come to a common understanding. Grant the first step and there is no difficulty in conceiving all the rest; but the supposition of that first step seems to involve an impossibility—a contradiction. The infancy of society is, in this respect, like the infancy of an individual. Every impression made upon the infant tends to influence its future moral and intellectual character; but when it awakens to consciousness of its existence and faculties, the period of its first existence is a blank in memory. It is the same with the infancy of society. The earliest annals of any nation; the earliest legends that have been borne down like pliant and flexible thistle-down floating on the breath of tradition, relate to a pretty advanced state of the development of the social mind. The foundations of society are laid in an age to which we cannot penetrate back to inspect them. And to this age the first faint stammerings of language must be conceived to belong. In our speculations upon language therefore, we must be content to take it as we find it—a full-grown and mature product, if we would not lose our time in vain and frivolous conjectures, which cannot be shown to have any counterpart in reality.

In treating of languages, or of language in the abstract, it will be found most advisable to confine ourselves to the consideration of such languages as have a literature,—as have, more or less, been reduced to a conformity with grammatical rules. We must always remember, however, that although every language that we know is learned by the aid of grammatical rules, and that although every highly cultivated language is in the latter part of its career fettered by the observance of these rules, yet that every language had attained its idiomatic character before these rules were invented or ever dreamed of. These rules are indeed nothing more nor less than descriptions of the actual state of the language at the time men began to frame them. They are not to be received implicitly even as descriptions of what the language is or was: they are to be compared with its actual state in order to ascertain whether they are correct or not. To know a language aright, we must be able to free ourselves from the pedantic fetters of rules, and study its living self. Rules are useful, indispensable to beginners; but when we have so far mastered the language, as to understand, speak, and think it, we must beware of fettering it by them. It existed before and independent of them. If we would know it in plastic vitality; if we would know its rich and shifting variety of forms, and obtain glimpses into its deeper spirit, wo must examine it for itself, without reference to mere rules.

Regarding language in this manner, and without seeking to wander from within the limits of literary languages, there is one fact that strikes us before all others. The form of language is determined by two laws—the one physical, the other intellectual, or, as it has been termed, logical.

The form of language is determined by a physical law. All language is a congeries of words—that is, of articulate sounds. Miraculously flexible as we know the vocal organ in man to be, still, the number of possible sounds is limited. It would even seem that no individual is capable of enunciating, or even of recognising by the organ of hearing, the whole range. There are guttural sounds in the Semitic language—that is the Arabic, Hebrew, and other languages of that class—which defy the organs of a European. The Hottentots have a peculiar cluck in their tone, which is understood to be indispensable to the right utterance of classical Hottentot, and which none but Hottentots, or children suckled by Hottentot nurses, have ever been able to acquire. There are whole states in the south of Germany, utterly incapable of pronouncing with certainty the letter *p* as distinguished from *b*, or *f* as distinguished from *v*. The impossibility to French organs of pronouncing *th*, to English of pronouncing *ch*, and many others, are examples of the same kind. With vowels it is still worse. We never yet met with an Italian who could pronounce the French *u*. Every people we find has a range of articulate sounds which it can pronounce and distinguish with facility by the ear. In every people, this range excludes articulate sounds which seem simple and easy to some other people, while that other finds insuperable difficulties in uttering or distinguishing what is easy to the first mentioned. This is the physical law determining the form of every language; and by it the variety in the forms of words in a language is limited by the range of articulate sounds which the nation speaking it is capable of uttering or recognising. There are other two facts which it is important to view in conjunction with this. The first is the tendency of all languages to split into dialects in consequence of this physical law; and so great may this become, that a person, tolerably familiar with the dialect spoken in one valley, may find himself utterly unable to understand that which is spoken in one at some distance. The other fact is, the likeness which minute acquaintance with languages at first apparently distinct, enables us to recognise in them the same words modified in form, but always modified in accordance with the dictates of this physical law. Tracing the action of this law onward, we find it working to produce more languages than now exist: tracing it backward, we find it carrying back several of the languages at present existing, to one common source; strongly tempting us to the conclusion, that all languages may possibly be mere variations of one original language. Applying this law practically, we can classify the various languages into families, all intimately related to each other. Thus, the Hebrew, Arabic, Ethiopic (of Abyssinia), Syriac, and Chaldaic, are found to form one great family of languages, called the Semitic. The Gothic, German (of different ages), Dutch, Swedish, Norse, &c., are found to form another great family of languages called the Teutonic. The relationship between these languages being established, not only is the acquisition of any one of them found to render the acquisition of all the rest an easy matter; but every additional language of a family that we acquire, renders our knowledge of those which we knew previously, more thorough and complete.

The logical or intellectual law which contributes to determine the form of languages, is a still more important element. The object of language is to communicate our thoughts to one another. Language consists therefore of a series of affirmations that we think so and so; or, as we generally conceive it, that a

thing is so or so. The longest and the shortest discourse are alike composed of a series of assertions more or less logically connected. Every separate assertion constitutes what is called by grammarians a separate sentence. The essential, the indispensable parts of a sentence, are three in number :—the subject, or the thing regarding which an assertion is made ; the predicate, or that which is asserted of the subject ; the copula, or that which indicates the connexion between the two. The subject is called by grammarians the noun, or the substantive noun ; the predicate, the adjective or adnoun ; the copula, the verb or word *par excellence*. Thus, " James is good," is a sentence. *James* is the subject, according to the phraseology of logicians ; the word James is the noun or substantive, according to the phraseology of grammarians ; *good* is the predicate according to the phraseology of logicians ; the word good is the adjective or adnoun according to the phraseology of grammarians : *is* is the copula of logicians, the verb of grammarians.

In the illustration selected, we have one simple example of each of the three ingredients of a sentence. Let us take one a little more complicated.—" James has been very unwell." Here James, as before, is the subject ; the predicate is expressed by the two words, " very unwell ;" the copula by the two words, " has been." The two words are in this instance made to supply the place of one. " Unwell," is a term so general, that it includes various kinds or degrees of indisposition, differing among one another, but the language does not possess enough of words to indicate each. The addition of the word " very," to the word " unwell," is made for the purpose of indicating one of these degrees. " Very unwell," is an attempt to supply the place of a word in which the language is deficient, by prefixing another word to one which it possesses, in order to indicate that it is used in a modified sense—in a sense somewhat different from that in which it is generally employed. " Very unwell," is as much a predicate, as much a single word, as the " good" in the previous example. " Very" is however a word which may be, and is prefixed to other words besides unwell, and with the same effect. It is therefore looked upon as a word of a particular kind—it is a word used, not to express either a subject or an attribute, but to modify inherently or restrict the meaning of a word employed to denote predicates. There are many such words in every language, and grammarians call them adverbs. " Has been," in like manner, are two words employed to supply the place of one ; in some languages we find no corresponding phrases, one word serving the purpose which these two words once had to serve in English. " Been" expresses or affirms simply the idea of existence without reference to time ; "*is*" affirms existence in the present time : the word corresponding with " has been," in languages which use only one word for the purpose we in this instance employ two to serve, affirms existence in past time. When the non-expression of time, or the expression of past or of present time is effected by a change in the structure of the word, grammarians call these words *tenses* of the same verb ; when the indication is effected by adding another word, that word is termed an auxiliary verb. Here then we have other classes of words with appropriate designations suggested by the specific use to which they are put.

In all these different classes of words, however, it is plain that it is nothing in the physical structure or primary original signification of the word which gives it its specific character. This specific character is the result of the intellectual or logical law determining the form of language : the use made of these words is the result of the habitual conventional practice of men to employ them for that purpose. Here we have a much more fertile source of difference among languages than in the physical law. One nation may habitually use two words to indicate what another expresses by one : thus the " have been" of the English is the "*fui*" of the Latin. Again, one people may have separate words to express the different degrees of indisposition, to indicate which in English we must call in the aid of adverbs—" very unwell," and " rather unwell." Again, these modifications of the form of a substantive which grammarians call cases, are effected differently in different languages ; the Romans did it by affixing syllables—annexing syllables to the end of the words ; the Hebrews did it by prefixing syllables—placing them at the beginning of the words. Yet again, the Greeks and Romans formed their plurals by altering the termination of their substantives ; in the old Teutonic languages, this seems generally to have been effected by a modification of the radical vowel. Traces of this method still remain in the modern Teutonic dialects. In German, the plural of *baum* is *baume ;* in English the plural of *brother* is *brethren.* In the old Teutonic languages in like manner, the modifications of the verb indicative of time was effected by changes of the radical vowel. In Latin, the same object was effected by means of changes of termination.

But the modifying effects of this logical law—already seen to be so numerous, while we have been restricting our attention to single sentences and their constituent words—becomes inconceivable when we take into consideration the number rendered requisite by the various devices adopted to show the connexion of sentences with one another—the nature of their inter-dependency. One example by way of illustration must suffice for this by far too wide field to enter upon. " John's illness caused his death." " John was ill, and John died." " John was ill, and therefore John died." All these three forms of speech are substantially the same. The object of all is to affirm two facts ; that John was ill,—that John died ; and to indicate that the one was the cause of the other. Some languages have a preference that they may more habitually use the form of expression which seeks to indicate the two facts by combining them into what seems at first view one simple assertion :—" John's illness caused his death." Others more generally have recourse to the mode of linking the two affirmatives together by means of a word employed to indicate the relation of causality :—" John was ill, and therefore John died." Others again, less advanced in intellectual culture, content themselves with simple juxtaposition, leaving the mind of the reader or hearer to infer the relation, as cause and effect, from the propinquity.

These are the two great natural laws which determine the character of every language. A language's aptitude to become the vehicle of thought will depend upon the degree of unity of physical organization, upon the native vigour of mind, the degree of advancement in intellectual culture which prevail among the people employing it.

There are other two circumstances to which we must now advert, that contribute most powerfully to modify languages. These are the circumstances of a language being subjected to grammatical treatment, and its becoming a written as well as a spoken language.

It would be apparent from what has been said above, even though we had no direct evidence to establish the fact, that a language might, under favourable circumstances, attain to a very high degree of refinement and development under the influence of the logical and physical law of its nature, before it received any assistance from the hand of art. Among a people finely organized like the Greeks, and like them operated upon by a thousand awakening influences, the mind becomes of necessity capable of great delicacy of sentiment, and powerful and acute intellectual exertion even before it turns its eye inward to reflect on the phenomena of its own operations. Great wealth of words is required to express its multitudinous conceptions, and great delicacy of modification in the structure of these words to indicate its nicer shades of thought. Such an influence necessarily engenders a wealthy and expressive language. Correct habits of thought give unconscious correctness of expression ; a nicely attuned ear, and a pliable organ of speech, give at once nervous and harmonious structure of sentences. The language is found formed, and well formed too, when the grammarian first sets himself to analyze it. He finds wealth and variety not only of words, but of classes of words, marked and sanctioned by long habitual use. He finds beauties of expression which suggest his rules, instead of being produced by conformity to them. But from the moment that men set themselves to grammatical analysis, a change takes place in the future development of the language. From that time men not merely speak well—they are conscious at the time that they are speaking well, and are taken up with the thought. The language gains in correctness, but loses in freedom. It is less unequal, more sustained in its vigour and elegance, but no more savours of a grace beyond the reach of art. It is owing to this that a language may be subjected to grammatical treatment at too early a period of its development for its future healthy growth. This is more particularly the case when it is prematurely subjected to this treatment, having learned it from another people whose language is farther advanced. In this latter case, in addition to the withering and cramping effect of such untimely conforming to rule, it is in danger of attempting to transplant what is good in the more ad

vanced language, but that withers in the alien soil, and blights at the same time native beauties which might have sprung up but for its baneful shadow.

The other modifying circumstance to which we adverted, was that of a language becoming a written as well as a spoken language. A merely spoken language is a living organic thing. Sound is its body,—thought is its soul. Articulate sound is the physical frame, enabling the animating thought to manifest itself, and serving as an engine to work its will. When spoken sounds were first represented by characters, these characters were only of importance as suggesting the familiar sounds. But when at a subsequent period the art of writing was perfected, and came into daily and familiar use, it modified language considerably. Men began to form their conceptions of words less with reference to their sounds than to the characters meant to represent those sounds. More particularly was this the case with those languages which had borrowed the art of writing from foreign nations, and in so doing simply adopted their characters—as was the case with the greater number. This servile borrowing was the cause why the characters adopted to represent the sense of the original language could not correspond exactly with the different range of sounds of the borrowing nation. There arose hence a vagueness and want of fixity in the apprehension of the sound indicated by several characters; and sometimes an awkward attempt was made by a combination of two characters, to represent a simple sound. Thus, all the nations of modern Europe employ the same alphabet, but the sounds expressed by the same characters differ widely. The same character expresses *u* in Italian, *u* in French, and an almost infinite variety of sounds in English. The same character (*c*) is sounded in Italian as *k* or *ch* (church), according to its position; in English as *k* or *s*. *Ch* is used sometimes to indicate *sh*, sometimes *ch*, sometimes *gh*.

We have hence as it were two distinct languages in every country—the language of the recluse student speaking to the eye—the language of the mere man of business speaking to the ear. Of course it is the cultivated intellects of every nation that we are to look to for what gives vitality and beauty to its language, but the deadening influence of the eye-language palsies their tongues. The written language becomes of necessity meagre, unrhythmical, and formal. It becomes stunted and unsusceptible of clothing new and original forms of thought.

The language of every nation is a part of its history—an enduring monument, in so far as it has been preserved, of what it did, as well as the medium through which we learn its adventures. The special history, therefore, of the language of each of the nations of which we shall have to speak in the subsequent and illustrative part of these lectures, will fall to be treated of under the general head of its general history. It may not however, be altogether useless to advert to them here in mass; not so much for the purpose of indicating the characteristic features of each, as of showing their mutual relations and bearings upon each other.

The languages of the nations we shall have to speak of may be divided into four classes:—

The Hebrew, belonging to the Semitic family.

The Greek and Latin, belonging to the Indo-Germanic family.

The various Teutonic languages, belonging to the same family.

The Romanic languages, compounded in various proportions of the Latin and Teutonic elements.

There are other languages which still prevail in parts of the nations of which we shall have to speak, which once prevailed to a greater extent. Nor have these, together with some that are now extinct, been altogether uninfluential in determining the specific development of other languages which play an important part in the history of European civilization. But that influence has been so indirect, that we are left rather to conjecture than to know it. The influence of their original Celtic tongue on the habits of thought and speech of the inhabitants of Gaul or France, must have been strong; for, although every word of that language has disappeared from that which they now speak, some of the most striking peculiarities of Celtic pronunciation continue to characterize the French mode of enunciating their mixture of Teutonic and Latin. In the later Greek of the Roman empire, we can trace Orientalism drawn from the thousand tribes of Asia over which the Greeks obtained the ascendancy. And the modern Greek of the Morea, with scarcely an alien word added to it since that time, is nevertheless pronounced, not with the old Greek accent and intonation, but with those acquired from the Sclavonic invaders who have imposed new names upon almost every village in the Morea, without being able to add one word to the domestic prattle of its women.

For our present purpose, it is unnecessary to touch upon the Hebrew language more particularly. Its history is as isolated as that of the people whose name it bears. It borrowed nothing of moment from them, and it communicated as little. The very grammatical theory was formed apart and uninfluenced by theirs.

The three remaining classes have, independent of every other consideration, a community of character,—the consequence of the adoption of the same grammatical system. Here, as in every department of European knowledge, we again trace the influence of the school of Alexandria.

Among the earliest theorizers in grammar was Aristotle. This universal scholar recognised only three parts of speech; corresponding to the subject, the predicate, and the copula. It was chiefly among the Stoics that this branch of knowledge was cultivated, from this time until the school of Alexandria reached its maturity. The Stoics carried their classification of words to a greater degree of minuteness; they distinguished, in addition to the three classes of Aristotle, the article, the preposition, the participle, and the adverb; and separated the one class of noun or substantive into three,—the substantive, the proper name, and the pronoun. The Alexandrian grammarians introduced a greater degree of precision into their classifications, and extended their speculations to embrace the phenomena of the most prominent dialects of the general Greek language. The grammatical doctrines of the Alexandrian school were adopted wherever Greek literature was cultivated. The Romans attempted to apply them to their own language, and not altogether without success. The first notions of grammar introduced among the northern tribes who settled on the ruins of the Western empire, were derived from churchmen who were taught in the Roman school. The prevalence of the Latin language, as the general medium of communication during the middle ages, was the occasion of its being, during these ages, the only language studied grammatically. If by chance any one attempted then to form a grammatical system of his mother tongue, it was simply by transferring to it the grammatical formulas of the Latin. When the final overthrow of the Eastern empire, at the taking of Byzantium by the Turks, drove a number of accomplished Greeks to seek safety in Europe, and there to assist in the revival of literary taste, it was found that they had been taught in a grammatical school, almost identical with that which prevailed among the western nations. We cannot wonder at this, for we have seen that both had descended from the teachers of Alexandria; but this served to confirm the power of the grammatical theory taught by both. Accordingly, when with the rapid advance of the modern languages both in the development of their own power of conveying thought, and in the rich stores of intellectual and imaginative treasure contained in them, they grew to be considered of sufficient importance to render a regular grammatical system of instruction in them desirable, it was natural that the scholars applied to for this purpose should attempt to clip and twist them to suit the grammatic formulas with which they were already familiar. With the Romanic languages this was easy. Latin idioms and vocables constituted the greater part of their store. The more stubborn Teutonic tongues were forced to yield to circumstances, and adapt themselves to their new dress as best they might.

But independent of this systematical influence, there were circumstances at work in society bringing about *rapprechements* of their different tongues. The Grecian dialects, most sharply distinguished during the first and most luxurious bloom of Grecian literature, became blended and assimilated to each other by the progress of events. In this period of the Roman empire, some affected to write one dialect, some another; and it was in this manner that Spenser wrote an antiquated dialect, which although not that of his own age, was as certainly not that of any age that preceded it. The literary Greek language of that age is one; and this language, with wonderfully little admixture—with merely such idiomatic and verbal changes as time necessarily brings about—continues to be the modern Greek of our day. The Latin language, as we now possess it in the classical writers, was in all probability never in that exact form the popular spoken language of Rome, or any part of Italy. It is a highly artificial language, dressed up to suit the taste of those who had been trained in a foreign language to think with foreign thinkers,

That foreign language was Greek. The materials, however, of the popular tongue, whatever we may think of the form, were essentially the same as we find in the classical writings; and these materials were composed of two elements. The first and by far the most preponderant was Greek—that Greek which, long before the age of Roman literary refinement, was spread through the peninsula of Italy, from the free towns of that part of it to which the name of Magna Grecia was given. The other element was Ascan, of which some remains are still preserved in old rude inscriptions, sufficient to show us whence the Romans derived certain of their words and terminations alien to the character of the Greek language—a language in which, as we learn from the classical writers, plays were frequently acted in Rome at an advanced period of the republic, for the pleasure of all classes of the citizens. This *lingua franca* of Greek and Ascan seems to have been latterly the language of southern Italy wherever Greek was not spoken. The artificial Latin language, the use of which in the natal soil of Rome was confined to comparatively few, obtained a wider range in those provinces subjected to the sway of the Imperial city in which Greek was not spoken. In the old Carthaginian territory, and the yet more western states of northern Africa; in Spain, Gaul, South Britain, Rhætia, and Dacia; the classical Latin became first the language of public business, then the language of polite life, latterly, the language of all—superseding in a great measure the native dialects. The Roman language never gained a footing east of the Rhine, the remains of it in Britain were submerged by successive tribes of Anglo-Saxons, Tutes, and Danes. The limits of the provinces speaking Latin and then speaking Teutonic under the Empire, are the limits of the provinces speaking Teutonic or Romanic in the present day. After the fall of the Empire, the local mixture of Ascan and Greek continued to be the language of the greater part of Italy. Many Teutonic forms of words and phrases were adopted in the Latin provinces from their conquerors, but the more cultivated tongue maintained its ascendancy. It is to this circumstance that we are to attribute the seeming anomaly, that Spanish—the language of what was only a Roman province, with a stranger admixture of Teutonic, and with even a breathing of Arabic—approaches more nearly to the classical language of Rome, than even Italy, the native home of Romans.

It follows from this retrospect, that the languages we have been speaking of stand in the following relation to each other :—

Greek is an original language, almost pure from foreign admixture.

Latin is a Grecised form of a language compounded of Greek and Ascan.

Modern Italian is the descendant of this mixture of Greek and Ascan—in the north, with an admixture of Teutonic words and phrases.

Modern Spanish, Portuguese, French, and Walloon, are languages Latin in their structure, with a large admixture of Teutonic words and idioms.

English is a language of Teutonic structure, with a large admixture of Latin and Romanic words.

German, Dutch, Danish, Norwegian, and Swedish, are Teutonic languages.

It appears from this conspectus, that of the elements composing the ancient and modern languages, by far the greater part in the European system are extremely simple. Greek, Ascan, and Teutonic, variously mingled, are the ingredients of all. They have, moreover, all of them been moulded in their literary, that is, in the most important part of their development, by means of one and the same grammatical system. This has effected a still greater similarity among them. However much their words, and however much some of their idioms may vary, European thought is essentially cast in the same mould. The same formulas of thought pervade them all, and find expression in them all. Whoever has mastered the two eldest, one of the modern Romanic, and one of the modern Teutonic tongues, may with a little trouble, —by the knowledge he has acquired in the process of learning the grammatical system common to all—easily master any or all of the others. Such knowledge of language is, on the Continent, no uncommon phenomena among men addicted to business. Nay, it is not impossible, that in this age, when so much attention is devoted to the art and science of teaching, that some one may, ere long, by attention to the general physical and logical laws of language, and to the more accurate classification of the ancient and modern languages of Europe, render such lingual accomplishments a matter of easy attainment.

The advantage of this smoothing of the road to the acquirement of languages to all classes of a mercantile community, we need not point out. To merchants, a knowledge of languages is of the greatest consequence; and now-a-days, that our shipment of artisans to foreign countries is becoming so common, to that valuable class of the community also, such an improvement in the art of teaching languages as we have been indicating, would be most important.

It is, however, mainly with the advantage it would afford to the student of history, we have to do at present. The power of studying historical documents in the original is of immense importance. No translation ever can give an adequate conception of the spirit of the original. Even admitting the possibility, how are we without a knowledge of the original to ascertain the fact? The original is direct testimony; the translation without it is mere secondhand or hearsay testimony. Again, a knowledge of the language of a people furnishes us with a key to their thoughts and feelings, which nothing else can give. Lastly, possessing the power of reading historical documents in the original, we are furnished with access to a species of corroborative evidence of the highest importance. To one skilled in languages, the structure of the language of a document often furnishes the means of referring it to its real age, and thus of either establishing its authenticity, or proving it to be a forgery.

We have now concluded that portion of our subject which relates to the general principles of historical research. We have laid before our readers a rapid survey of the sources of historical information. We have endeavoured to elucidate the rules by which to value that evidence. We have traced out an outline of the sciences of chronology, geography, and language, and their respective histories. We have endeavoured to explain the importance of these studies to the historical inquirer, both as preparatory to the investigations necessary to enable him to apprenend history aright, and as furnishing adminicles of evidence more or less direct. These topics embrace all that seem indispensable to the student of history; although, but for extending the introductory chapters to too great a length, many more might have been introduced with advantage.

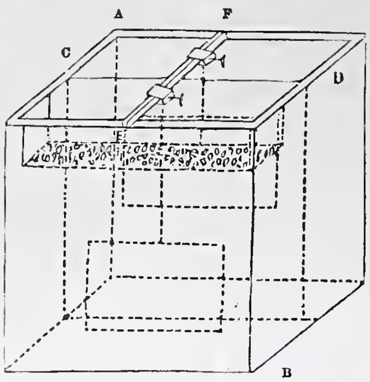
In our next chapter, we commence that portion of our subject which is intended to be illustrative of the practical application of the principles we have endeavoured to unfold.

## THE ELECTROTYPE

Electricity is rapidly extending its boundaries, and becoming every day a more and more important agent in the arts. "It is," says Professor Daniell, "as widely diffused, as energetic in its character, and at least as important in the economy of the material universe, as heat itself; but its properties are more recondite; and necessity has not yet given to the human race that early command over this power, upon which its very existence has depended in the latter case. Such a command will probably result from the higher exercise of the intellectual faculties of man, and may be destined to requite his patient industry with the acquirement of power, of which only inadequate anticipations can, as yet, perhaps be formed." Already have we seen it successfully applied to many useful purposes, and in none more so than to indicate the progress of time, to convey intelligence at the rate of about 200,000 miles in a second, to ascertain the depths of the sea, and by the process which we are now about to describe, to copy with *perfect* accuracy engraved copper plates, medals, seals, &c., and gild, plate, and etch, with great beauty and precision.

The science of electrotype was discovered by Mr Thomas Spencer, of Liverpool, in 1839, and first made known to the public at one of the meetings of the Liverpool Polytechnic Society, on the 12th September of the same year. It was also discovered on the continent by Professor Jacobi. The process is remarkably simple—indeed, as much so as it is beautiful—and any person with a little patience and perseverance may satisfy himself of the fact. In its simplest form it may be described as follows :—

A box A B is procured, varnished in the inside, and having a thin partition C D of any porous wood, dividing it into two unequal cells; sycamore (plane-tree), is sometimes used for this purpose, and found to answer very well. Across the box, or at right angles to the thin partition, a rod of metal E F is placed, having a screw fixed upon it above each cell. Into the larger cell the copper plate or mould which is to receive the deposit, is suspended by a copper wire, which is attached to the metallic rod E F by means of the screw; and into the other a piece of zinc of about the same size is suspended in the same manner.




The rod of metal is merely used as a convenient means of forming the connexion between the mould and the zinc. The larger cell is filled with a solution of sulphate of copper (blue vitriol), and has a little shelf fixed near the top, to contain crystals of the salt, so that the supply may be kept up. The other cell is filled with a half-saturated solution of hydrochlorate of ammonia (sal-ammoniac). Common culinary salt may be employed instead of the salt of ammonia.* Before the mould, if it be a conductor, is put into the box, it should receive a coat of varnish, consisting of spirits of wine and wax on the back and sides, and all parts upon which the deposit is not required. The wire also which suspends the copper mould ought to be varnished; and care must be taken that the varnish is thoroughly dry before the mould is used. The arrangements being completed—the mould plate which is to be copied being placed in the solution of the cupreous salt, and the zinc plate in the exciting fluid and the metallic connexion being completed—electric action immediately commences; the current passing from the zinc to the mould-plate, as in the simple galvanic circuit, decomposes the sulphate of copper in its progress, and precipitates the pure metallic copper upon the mould-plate. The time to continue the action depends entirely upon the thickness of the deposit required. Five or six days are generally allowed, and it will be necessary during that time, to add both sulphate of copper and muriate of ammonia as often as required. The mould can be taken out at any time and examined, without being in the least injured. If it is an engraved plate, it must be remembered that the deposit upon it, although a fac simile of the original, is only a copy *in relief*, and that this copy has to be subjected to a similar process, and that the copper realized upon *it* will be a *real* copy of, and answer the purpose as well as the original plate. Any number of copies can be produced from the plate in relief, and equally as good as the first. It will be sometimes found difficult to remove the newly produced plate; but if previous to the operation the plate be heated and rubbed on the surface with bees' wax, and then cleaned by rubbing it with cotton while the heating is continued, this difficulty will be removed. When the deposit is received on a mould, suppose of a medal, the mould stands in the same place as the relief plate, and consequently the deposit upon it is a duplicate of the medal. Moulds of a great many objects can be taken, such as seals, medals, medallions, plaster-casts, &c., and any number of copies produced. They are prepared in various ways, and great care must be taken in their execution, as upon it entirely depends the minuteness of the future copy. Mr Walker, honorary secretary to the London Electrical Society, who has written a very excellent little work on Electrotype Manipulation, says:—"There are many materials fitted for forming moulds; but of these I recommend three, which will be found to answer most purposes; *fusible metal*, *wax*, and *stearine*. The first is applicable to all medals of ordinary size, the second to plaster medallions, and the last to larger medals."

"*Fusible Metal.*—This is an alloy, consisting of bismuth, tin, and lead: it melts at a low temperature, a few degrees beneath that of boiling water: and has been used as a philosophical toy, in the form of spoons, which melt in hot tea. For this purpose it generally contains a small portion of mercury. Since the discovery of electrotype it has been prepared for that purpose, without mercury, and may be obtained at most of the philosophical instrument makers.

"The proportion of the different ingredients in a pound of this alloy, are 8 oz. of bismuth; 3 oz. of tin; and 5 oz. of lead.† These should be melted together in a *clean* iron ladle, taking care to keep it on the fire no longer than is necessary to produce the complete liquefaction of the several ingredients. When melted, pour the metal on a stone or marble slab in drops. Then after having *rubbed the ladle clean* with coarse paper, return the pieces of metal, re-melt them, and pour them out in drops as before. A third melting will ensure the ingredients being well mixed. There is very little fear of failing in converting this metal into moulds, if the ladle is rubbed between each melting, and if the metal is removed from the fire the *instant* it is melted. The former ensures a bright surface to the mould; the latter preserves the alloy from change by oxidation."

"*To make a mould in fusible metal.*—Melt some in the iron ladle, and pour it on a slab; then from the height of two or three inches, drop on it the medal to be copied, taking care that the medal is COLD. In a few *seconds* the metal will be solid, and may be placed to cool; when it is cold, either with or without a few slight taps, the two will separate, and if proper care has been taken, an *exceedingly sharp* mould will be obtained.

"*Wax moulds.*—The manipulation with this material is very simple. The wax employed is the common white wax, or the ends of wax candles. It is to be melted in an earthen pipkin, and kept on the fire a few minutes after it is well melted. The medal to be copied should be made warm, the warmer the better, (the object being to prevent the sudden chill of the wax when poured on.) It is then surrounded with a rim, composed of a riband of pasteboard. The end of this may conveniently be secured by a small *cleft stick*. The surface of the medal should then be very slightly covered with olive oil. The hot wax is then poured on. It will require five or six hours to become sufficiently cold for removal.

"*Stearine moulds.*—There will be at times a difficulty in removing wax moulds from medals with elaborate work. If this is the case, boiling water should be poured into a cup, or any vessel smaller than the medal, and the medal, with the wax upward, should be placed on this. The sudden influx of heat will expand the metal, and generally cause the separation without further difficulty. This will occur in a *few seconds.* To avoid this trouble and uncertainty, *stearine* will be found a far better substance than wax; it very rarely adheres to the metal, especially if the latter, when practicable, have been previously rubbed with *black lead.*"

The author in the second part of his work gives a composition to be used instead of wax and stearine. He says:—

*Composition moulds.*—The following mixture has been lately recommended, as being very serviceable for mould making:—

| | |
|---|---|
| Mutton suet, previously melted and strained, | $1\frac{3}{4}$ lb. |
| White, or virgin wax, . . . . . | $1\frac{3}{4}$ — |
| Spermaceti, . . . . . . | $\frac{1}{2}$ — |

These are to be melted together, and used precisely in accordance with the directions given for wax, &c. "To copy plaster-casts," Mr Walker says, "pour some *boiling* water into a plate; stand the cast *face upward* in this water: the water must not be deep enough to reach the *face* of the cast. In a few minutes the cast will be filled with water. Then, without loss of time, wrap round it a riband of pasteboard as before, and *immediately* pour in the melted wax. After the wax is solid, let it remain for two or three hours, and the mould may generally be lifted off from the plaster without further trouble."

It must be evident to every one who knows anything about the science of electricity, that moulds made of non-conducting substances, such as wax, &c., will not receive the deposit, and without some plan of rendering their surface conducting, they would

* Sulphate of soda (Glauber salt) is preferable to either of these salts. Sulphate of magnesia (Epsom salt), may likewise be employed. If, however, it is wanted to deposit *crystals* of copper (as upon a greasy metallic surface), then a strong solution of culinary salt is the best excitant.

† Rose's fusible alloy, composed of 2 parts of bismuth, 1 of lead, and 1 of tin, fuses at 200° and is therefore preferable. It may be employed for taking casts even from the surface of wood and embossed paper.

be of no use in electrotyping. Many methods have been thought of for accomplishing this, but the best and simplest is that discovered by Mr Murray in the beginning of 1840. It consists in rubbing plumbago, or black lead, on the parts of the mould that is to be copied. It is preferable that a camel's hair pencil be employed for this purpose. The rubbing ought to be continued till the surface of the mould has a fine black lead polish, and care must be taken that the plumbago, which is applied dry, be equally distributed over the surface.

In fixing the plates and different kinds of moulds to the copper wire, which is fixed to the rod of metal crossing the box, there is a little nicety required. If it is an engraved plate, the wire should be flattened at the end and soldered to the back of the copper. In fixing the wire to a mould made of fusible metal, Mr Walker says, " The end of the wire must be *quite clean;* the wire is placed across the flame of the candle, with the clean end beyond the flame ; it is to be touched with a piece of rosin, and pressed on the edge of the mould. The mould will instantly melt to receive it, and in a few seconds it will be cold and firmly fixed." In attaching the wire to wax moulds, it is only necessary to heat the wire a little and press it against the back of the mould, but care must be taken to form the connexion between the wire and the face of the mould, by rubbing a small part of the wire, and the wax between it and the plumbago surface, with plumbago. The wire is soldered to any side of the zinc plate.

We have all along spoken only of multiplying engraved plates, medals, seals, &c., by electrotype manipulation, but not only these, but any other objects that can receive a coat of plumbago may be copied,—pipes, boilers, stew-pans, and various other vessels can be produced of solid copper in this way, and several patents have been secured for the application of this process to the manufacture of many articles of that kind. It is a very good and easy method of making the copper cells of a galvanic battery. But many of the numerous sorts of vessels which may be produced by taking advantage of this process must be evident to every one ; and in the mean time we stop here, leaving the arts of electro-gilding, electro-plating, and electro-etching, till a future time.

A.

## COAL-FIELDS OF GREAT BRITAIN

### CHAPTER III.

#### UPPER DIVISIONS OF THE UNDER COAL FORMATION OF THE VALLEY OF THE CLYDE.

In the fourth number, we described in a brief manner the general character of the upper coal formation of Lanarkshire. Before noticing those that underlie the beds of fresh water origin, it may be necessary to mention that, from the basin-like form of the formation in question, we are convinced that it originated in a lake, probably connected with another on the east, which stretched through the counties of Stirling and Linlithgow, into that of Fife, and not in an estuary. Another proof is, that wherever the upper beds are observed in contact with those of decidedly marine origin, we have proofs of great disturbance in the occurrence of numerous faults and troubles in the stratification ; and this point of contact commonly occurs at a considerably higher level than the central parts of the basin, except at its western extremity near the city of Glasgow, where denudation (1) has taken place to an enormous extent.

The faults of the upper coal formation of the valley of the Clyde generally run from east to west. They vary in extent from a few feet to seventy or eighty fathoms ; but in the neighbourhood of Glasgow, they run from north-east to south-west, and are so abundant, particularly to the west of Govan collieries, that strata nearly two hundred fathoms distant, in the vertical section, lie at the same distance from the surface in contiguous fields. The faults are, apparently, all upthrows in the direction of the tract occupied by the lower formations. Denudation seems to have taken place to a much greater extent on the south side of the Clyde than on the north, insomuch that we have several marine limestones occurring between the lower coal beds on the north side of the basin, while on the south, only one or two are known. The real position of these limestones, and of the subjacent strata to the coals constituting the upper series was not known, till the writer of these articles, in 1836, made the survey of the district,* and was afterwards engaged in superintending the mineral researches made by the magistrates of Glasgow in the lands belonging to the city. By these researches, and others made in the district, he determined the existence of these limestones interposed between the lower and the upper coal strata, one of which, the calm limestone of Bedlay, had only been known, or if the others had been discovered, no knowledge whatever as to their true position existed. A knowledge of these beds is of the utmost importance in understanding the geology of our coal fields, forming, as they do, an excellent index to the nature of the stratification on either side of their outcrops. The limestones are well defined as to their mineral composition, thickness, and accompanying strata. The first bed, of which we have positive knowledge, is the calm limestone of Bedlay and Garnkirk. It consists of two layers of compact blue limestone, each nearly three feet thick, with a parting of encrinal(2) shale about eighteen inches thick. It is overlaid by a bed of blue friable shale measuring from twenty to fifty or sixty feet in thickness, and containing occasionally producta(3), encrini, and orthoceratites(4).

The limestone is slightly ferruginous. It contains rather more than 40 per cent. of lime. It is wrought principally for the supply of the iron works near Airdrie and Glasgow, at the following places :—Petershill, Milton, Garnkirk, and Bedlay. It ranges east and west from the neighbourhood of Cumbernauld to Glasgow, a distance of about twelve miles. Though it evidently underlies the upper coal strata, I have not met with it on the other side of the basin of the Clyde ; unless indeed a stratum formerly wrought at Cathcart, three miles to the south of Glasgow, be identical with it, as also that of Arden, near Thornliebank. One evidence that this is the case is, the occurrence of a bed of bivalved shells, resembling the posodonia, in the floor of the limestone at Petershill, Milton, and Thornliebank. In each case, these shales have a metallic lustre, being converted into, or enamelled with, iron pyrites. The limestone at Thornliebank is attended by a shale in which there were found a great variety of organic remains, particularly spiriferæ(5), producta, and the conularia, quadrusulcata(6). But the place where these were found, so abundantly, has been long closed up or built upon.

At a little distance beneath the calm limestone, there sometimes occurs a thin coal : the only place where it has been attempted to be wrought is at Garnkirk, where it was fully two feet thick, and also at Hoganfield at Glasgow, where the coal is very thin and partial but of a good quality.

For about thirty fathoms below this limestone, the strata consist solely of shale, faikes, sandstone, and also fire-clay, of which there is a very thick and excellent bed immediately below the limestone, particularly in the town's lands at Petershill. At the distance above mentioned, there is a ferruginous limestone eighteen inches in thickness ; and at a further distance of nineteen fathoms, a limestone of similar quality and thickness. The distance from this limestone to another stratum of similar quality and thickness has not been determined, but it occurs near St Rollox works, and in the tunnel of the Edinburgh and Glasgow Railway at Glasgow. It underlies a bed of laminated sandstone, between which and the limestone there is interposed a bed of faikes and another of shale, about nine feet thick, which contains producta, goniatites(7), euomphilus discors, nucula clausiformis(8), and tumida, small orthoceratites, encrinitis, &c.

About five fathoms below the last mentioned limestone, there are two seams of coal, one sixteen inches, and the other twelve inches thick ; two or three fathoms below which lies the thick bed of coarse gritty sandstone, which has been so extensively wrought at Cowcaddens quarry, Glasgow, and at the place which now forms the terminus of the Edinburgh and Glasgow Railway. This sandstone is from eighty to ninety-five feet thick : sixty feet or more of it is coarse and pebbly, but the under layer is finer in the grain and whiter in colour. The lowest of the upper limestone lies about fourteen fathoms below the sandstone. This limestone is of very excellent quality ; but has not been yet

* See Mr. Craig's Report on the Coal Formation of northern Lanarkshire, in Transactions of the Highland and Agricultural Society of Scotland for 1837.

wrought. It was first discovered by Mr Neilson of Oakbank, in a well at the western end of his house. I afterwards found it within five feet of the surface in Pinkstone bog, near St Rollox works, and in several other places in the town's lands. It is compact, and of a slate grey colour, and measures from four feet seven inches to five feet four inches in thickness: it contains above 90 per cent. of the carbonate of lime, and about 4 per cent. of iron. There is a thick bed of shale above it, containing nucula, goniatites, and other marine remains. The nuculæ occur abundantly in the mass of the stone. These limestones have been cut through in the Glasgow Tunnel.

There is no coal beneath the limestones for at least twenty fathoms; but there are several seams between twenty and thirty fathoms down; none of them however appear to be of any value. Below these, but at a distance not yet accurately determined, there are several seams of coal, and two black band ironstones, now wrought to the north of the city in the lands of Keppoch, North Woodside, Jordanhill, and other places west of the city. These coals and ironstone occur also on the south side of the river, and are, or have been wrought at Ibrox on the Paisley Road, Titwood, and Cowglen, near Pollockshaws, and at Nitshill, near Hurlet.

The following are sections of this part of the strata taken, the one at Cowglen, and the other at Garbraid,—the one forming the southern and the other the northern limit of these deposits. It may be remarked that the black band ironstones are wanting in these sections: they appear to be confined to the central parts of the basin; and, also, that the coals in the central parts are not so thick as in the following sections :—

*Section of Cowglen Pits.*

| | fath. | ft. | in. | | fath. | ft. | in. |
|---|---|---|---|---|---|---|---|
| Surface, | 8 | 4 | 4 | Coal, | 0 | 1 | 4 |
| Strata, | 1 | 3 | 8 | Strata, | 6 | 4 | 0 |
| Coal, | 0 | 3 | 4 | Coal, | 0 | 1 | 0 |
| Strata, | 3 | 4 | 0 | Strata, | 4 | 4 | 0 |
| Coal, | 0 | 1 | 6 | Coal, | 0 | 0 | 10 |
| Strata, | 0 | 2 | 1 | Strata, | 0 | 1 | 5 |
| Coal, | 0 | 2 | 8 | Cannel Coal, | 0 | 2 | 5 |
| Strata, | 1 | 0 | 0 | | | | |
| Coal, | 0 | 1 | 9 | | 29 | 4 | 11 |
| Strata, | 0 | 2 | 4 | | | | |

*Section of the Garbraid Pits.*

| | fath. | ft. | in. | | fath. | ft. | in. |
|---|---|---|---|---|---|---|---|
| Surface, | 4 | 0 | 0 | Strata, | 10 | 0 | 0 |
| Strata, | 8 | 0 | 0 | Coal, | 0 | 2 | 9 |
| Coal, | 0 | 1 | 2 | Strata, | 3 | 3 | 0 |
| Strata, | 14 | 0 | 0 | Coal, | 0 | 1 | 8 |
| Coal, | 0 | 2 | 6 | Strata, | 5 | 3 | 0 |
| Strata, | 7 | 3 | 0 | Cannel Coal, | 0 | 3 | 4 |
| Coal, | 0 | 2 | 4 | | | | |

The cannel coal is the lowest workable seam in this division of the series. At Garbraid it consists of

| | |
|---|---|
| Soft coal, 6 inches. | Impure coal, 4 inches. |
| Gas coal, 2 feet. | Soft coal, 6 inches. |

There is often in connexion with this seam a black band ironstone, measuring from six to ten or twelve inches in thickness. This band is of good quality, and is wrought at present at Jordanhill, North Woodside, and Keppoch hill, on the north side of the river, and at Ibrox on the south. There is another black band lately wrought in Kelvin Grove, and at present in Keppoch, found in connexion with a soft coal, seventeen to eighteen fathoms above the cannel coal. It measures about a foot in thickness, and is also of good quality. There is doubtless a great abundance of these valuable ironstones in this locality.

Our limits forbid us to enter further upon the consideration of this portion of the strata. In our next, the lowest or clay ironstone series will claim our attention.

☞ (1) Being washed away. (2) Containing encrinites, the remains of marine zoophytes which had the appearance of a lily in some of their forms; hence they are also called crinoidians—lily formed animals. (3) Shells with two valves, one convex, and the other concave or hollow. (4) Chambered internal shells, straight and tapering, and pierced by a syphuncle or pipe. (5) A conical or pyramidal shell, with imperforated septa (divisions between the chambers) mouth half closed. (6) A flat spiral snail shell, angular in its convolutions and aperture. (7) Shells allied to the nautilus. (8) Small bivalve shells, allied to the ark shells, with many teeth on the hinge.

## PATENT STEAM TRAVELLING CRANE.

We present our readers with a drawing of Messrs. M'Nicholl and Vernon's working model of patent steam travelling crane.

The machine is adapted for the purpose of lifting and removing heavy weights at the goods-depôts of railways, in timber-yards, foundries, and other manufactories, and for the loading and discharging the cargoes of vessels.

This is the first instance of the threefold motions of a travelling crane being worked from a stationary engine. The three motions —the horizontal, the transverse, and the hoisting motions—may be worked simultaneously, or either of them may be worked independently, or any two of them may be worked in combination. The model exhibits the mechanical arrangements by which these effects are produced.

The efficiency of this machine may be judged of from the circumstance that one of them, with a 50-foot span, will travel 100 feet in a horizontal direction, with a load of three or four tons attached to it, in 45 seconds; and during the time the whole platform with the load is so moving, the load may be moving across the platform at right angles with the motion of the platform itself; at the same time, also, the weight may be raised or lowered as required. Cranes, on this principle, are being erected where the span is 53 feet, and the length of the tramway on which the platform travels is 266 feet, so that with one of these machines, the steam power is enabled to command an area of 14,098 feet.

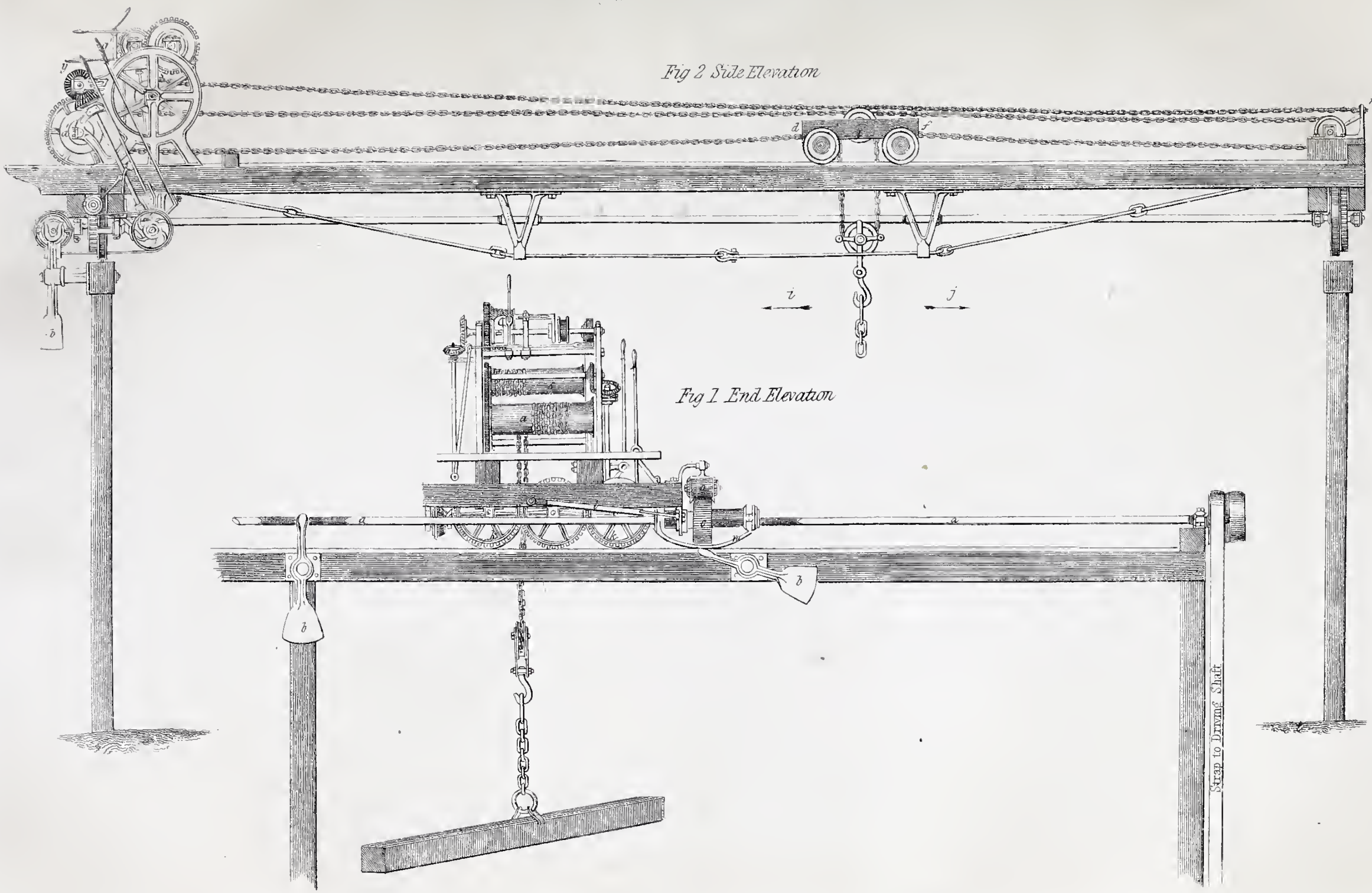
In addition to the immense saving in time that is effected by these machines, the saving in the wages of labour is very great: one youth, at ten shillings per week, who travels on the machine (for the purpose of moving the handles in and out of gear), displacing the labour of six men, at the same time doing the work more efficiently. At a recent experiment, this machine removed 13 logs of timber, containing 1,050 cubic feet, and weighing $19\frac{1}{2}$ tons, a distance of 100 feet, and piled them up in $27\frac{1}{2}$ minutes, at an expense in wages of about threepence. The machine had thus travelled 2,600 feet, and made 26 stoppages in the time named, with an average load of 30 cwt. for half the distance. Several of these machines have been in use for upwards of six months, working daily from morning to night, without stopping one hour for repairs.

This machine, like the ordinary hand-travelling crane, moves upon a tram-road laid upon longitudinal beams, raised from 15 to 20 feet above the level of the ground, the beams being supported at intervals by uprights. A square shaft, *a* ($2\frac{1}{4}$ inch diameter), runs the entire length of the tram-road, and is attached to the longitudinal beams by moveable supports *b*, *b*, *b*. This shaft is connected at one extremity to the engine. Upon it, and revolving with it, is placed a drum, *c*, which works, by means of a leather belt, the pulley *d* attached to the moving platform; the pulley *d* is fixed on the shaft *e*, upon which are placed the bevil-wheels, which impart the threefold motion to the crane. The bevil-wheels *f f*, which revolve on the shaft, are made so as to turn the bevil-wheel *g*, by means of the clutch-box *h*, which is attached to the shaft; so that by withdrawing the clutch-box from one of the bevil-wheels, and putting it in gear with the other, the motion of the bevil-wheel, *g*, is reversed, and when the clutch-box is out of gear, the bevil-wheel *g* is stationary. The bevil-wheel *g* is fastened upon the small shaft *i*, to the other end of which is attached the pinion *j*, which works the spur-wheel fixed to the roller-wheel *k*, and imparts the longitudinal motion to the whole platform. As the platform would otherwise move away from the drum *c*, which communicates the motion, it is made to slide freely upon the shaft, and being attached to the moving platform by means of the road *l*, it always preserves its relative position with regard to the pulley *d*. The difficulty of making the drum pass over the numerous brackets that a long shaft must neces-

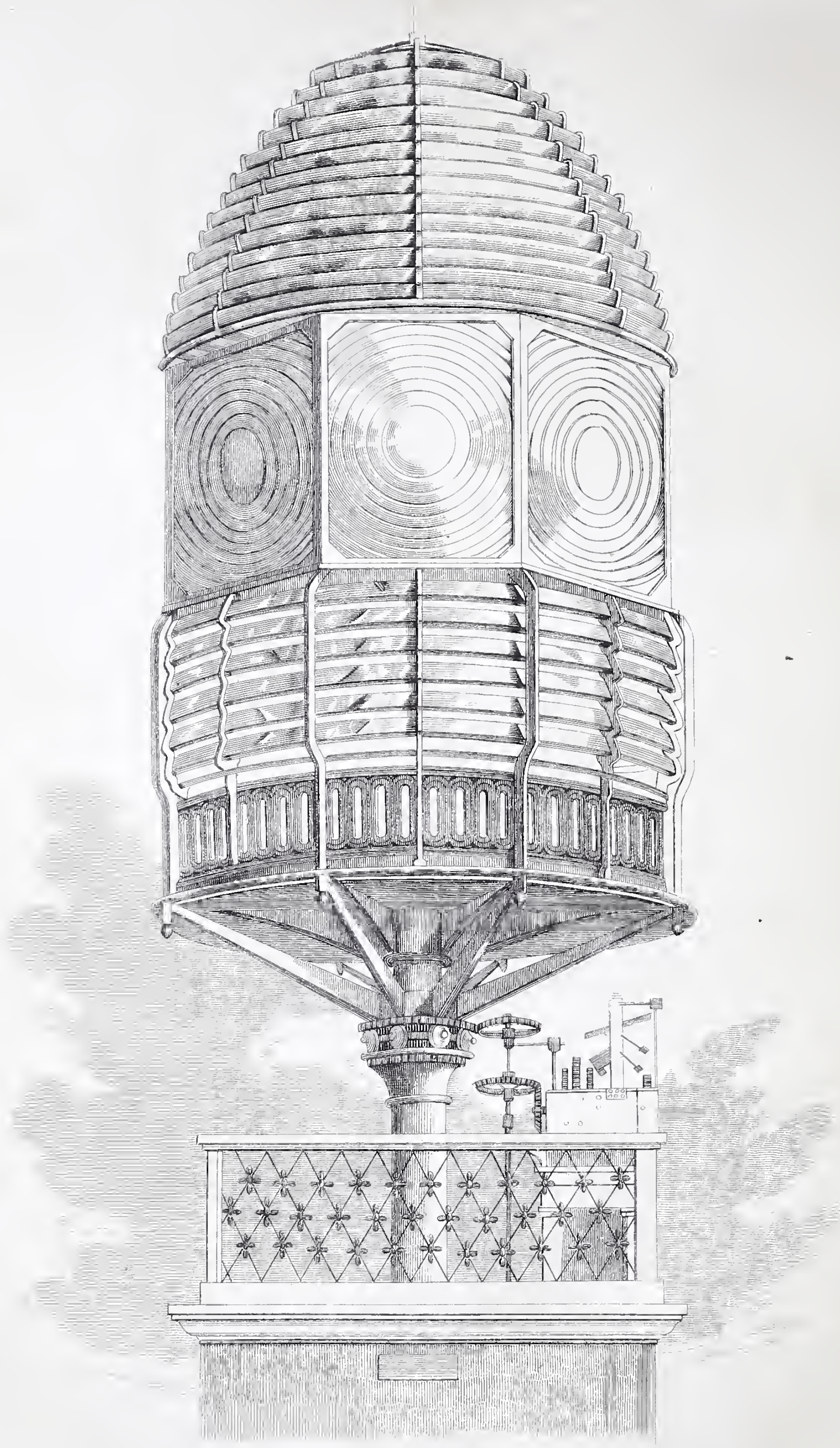
# PATENT STEAM TRAVELLING CRANE,

EXHIBITED BY M'NICOL & VERNON, LIVERPOOL

Official Catalogue Section II. Class V. N° 434.




*A Medal was awarded to the Exhibitors of this Machine*



DIOPTRIC REVOLVING LIGHT-HOUSE,

EXHIBITED BY CHANCE BROTHERS & Co BIRMINGHAM.

Official Catalogue Section II. Class X No.

sarily have to support it, is overcome by making the brackets swing on a centre, so that when the drum *c*, protected by the guard *n*, comes in contact with one of the brackets *b b*, it yields, as shown in fig. 1, and allows the drum to pass over it. Immediately it has so passed, the weight of the lower extremity of the bracket causes it to resume its position, and the machine passes on to the next bracket, where the operation is repeated. In order to prevent the shock that would be felt in putting in motion so heavy a body as a travelling crane of 50-feet span, carrying, in addition to its own weight, a load of three or four tons, a friction-roller *o*, is made to press upon the leather belt that passes round the drum *c* and the pulley *d*, so that before putting the maehine in gear, the friction-roller is raised; the machine is then put in gear, and the friction-roller gradually lowered. The momentary slipping of the belt round the pulley *d*, when the weight of the friction-roller is only partially resting upon it, causes the machine to move forward with an easy motion, and, directly it is under way, the friction-roller is allowed to bear with the whole of its weight, and the crane then moves forward with its load at its usual speed of 100 fect in 45 seconds. The hoisting motion is obtained by communicating the power through the bevil-wheels *q q*, and the shaft *r*, to the barrel *s*, round which the chain revolves. In order to render the hoisting motion independent of the transverse motion, the hoisting chain passes from the barrel round which it is coiled to the truck *t*, and after passing over the pulley *u*, under the snatch-block *v*, and over the pulley *w*, it is finally attached to the point *x*, at the extreme end of the platform. To hoist a weight, therefore, it is merely necessary that the handle *y*, which communicates with the clutch-box *z*, should be moved a few inches.

The transverse motion is imparted to the load by means of the barrel *'a*, which is worked from the shaft *e*, by the bevil-wheels *'b b'*, and clutch-box *'c*, in the same manner as the longitudinal and the hoisting motions. Two chains are attached to the barrel, in such a way that one winds when the other unwinds. One of these chains is attached to the small truck *t*, at *'d*, and the other is carried round the pulley *'e*, and fastened to the truck at *'f*, so that by alternately putting the clutch-box *'c* in gear with one or other of the bevil-wheels *'b 'b*, by means of the handle *'g*, the truck, and with it the load, is moved backwards and forwards along the platform at right angles with the motion of the platform itself.

Each of the above, the longitudinal, the transverse, and the hoisting motions, can be used independently of either of the others; or any two of the motions may be used in combination; or the whole three may be used simultaneously. For instance, at the same time that a weight attached to the hook *h'* is being raised from the ground by the barrel *s*, the truck *t*, and consequently the load suspended on the chain, may be moved in the direction *'i* or *'j*, at the same time that the whole platform may be moving in a longitudinal direction.

## DIOPTRIC REVOLVING LIGHT-HOUSE.

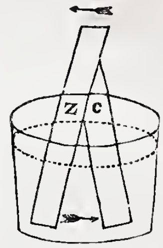
Dioptric apparatus of the first order, for light-houses, with revolving lenses and catadioptric zones, constructed according to the system of Fresnel. The upper and lower parts consist of a series of prismatic rings, each of which reflects, at the internal surface of its base, the incident rays of light. The middle portion is refractive, and produces, by its revolutions, a succession of flashes or blazes of light, for the purpose of enabling the mariner to distinguish any particular light-house. This revolving part consists of eight annular lenses. Each of these great lenses is composed of a number of concentric rings round a central lens, so as to produce all the refractive effect of a single solid lens of corresponding dimensions, but with less loss of light. The accompanying engraving represents this apparatus.

## THE GALVANIC BATTERY.

### CHAPTER I.

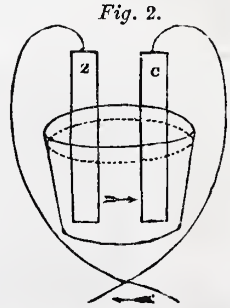
The principle of the galvanic battery is easily explained by reference to what is called "a simple circle." If a slip of zinc be partly immersed in a cup of dilute muriatic acid, no electric action takes place; but if a slip of copper be likewise introduced and made to touch the extremity of the zinc, active decomposition of the acid begins, and an electric current is in consequence instituted. The chlorine (one of the constituents of the acid,) combines with and dissolves the zinc, and the hydrogen (the other constituent of the acid,) makes its appearance under the form of minute bubbles on the surface of the copper. In this arrangement, the current put in motion passes from the zinc to the liquid, and from the liquid to the copper, along which it flows to tho point of contact, where it again passes to the zinc, and so on in a perpetual circuit. The passage of this current may be rendered manifest in a number of ways; but in none so simply as by immersing the plates separately in the acid, and connecting them by wires, as shown in the annexed figure.

*Fig.* 1.



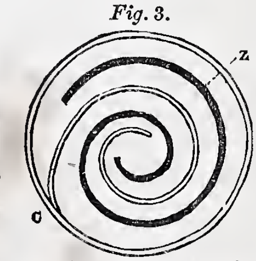

The circuit is thus much lengthened; but all the phenomena of the former arrangement ensue, and the current moves in the same direction, as is indicated by the position of the arrows. In this arrangement we have a very simple and convenient battery, which may be enlarged at pleasure by enlarging the plates. The large battery, for instance, constructed by Mr Pepys, for the London Institution, and described in the Philosophical Transactions of 1823, is exactly upon this principle. The only variation is, that the plates, which are each 60 feet long, and 2 feet wide, are coiled like a double riband round the cylinder of wood, and prevented from coming into contact by ropes of horse-hair, a non-conducting substance, interposed in various places betweeu them.

*Fig.* 2.



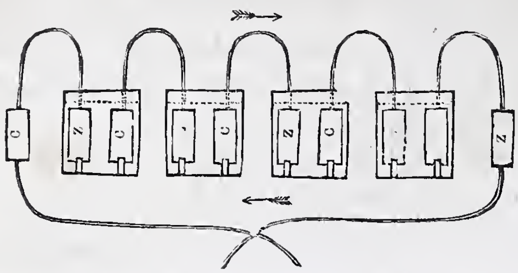

The first battery of this kind, on a large scale, was that constructed by Professor Hare, of Philadelphia, and called by him a *calorimotor*, from its remarkable power of producing heat. It consisted of sheets of zinc and copper, formed into coils, so as to encircle each other, and separated only by interstices of a quarter of an inch in width. The annexed figure exhibits a horizontal view of the plates as they are coiled together: the broad line z representing the zinc, and the narrow line c, the copper plate.

*Fig.* 3.




A battery composed of a single pair of plates of convenient size, is not powerful enough for many of the galvanic experiments which the student may wish to perform, but as any number of these may be connected together in such a way as to give a current equal in force to the sum of the forces of the single currents, we have the means of constructing batteries of any required power. This is illustrated by the arrangement shown in the following figure. The parts, of course, may be of any size we think necessary or find convenient; but we have supposed here that they are simply so many tumblers with small plates, one of zinc and another of copper, placed in each; the plates may be prevented from touching each other by bits of wood or cork, and the liquid employed may be very dilute sulphuric acid (as vitriol 1, and water 20, by measure.) The simple currents, generated in the individual cells, will be understood from the description already given of Fig. 2; but here the current generated in any

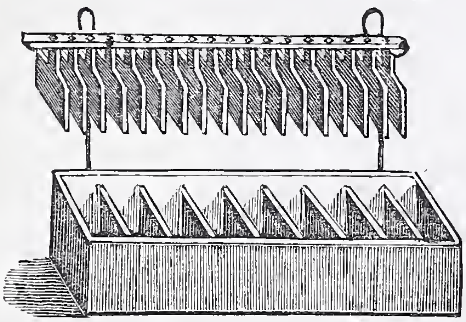
*Fig.* 4.



cell on the left of another, passes into the cell on the right of it, and adding itself to the current there generated, passes to the next; so that the accumulated current, when the extreme wires or *poles* are in contact, passes through the arrangement in the direction of the arrows. But it will be observed, that when the connexion between the poles is broken, the electric action ceases; this is shown by the copper plates ceasing to evolve hydrogen gas.

A more compendious form may be given to the arrangement by employing a trough divided into a number of compartments by partitions, and made of non-conducting materials. Wedgwood-

*Fig.* 5.



ware answers best, but well-baked hardwood with partitions of glass answer very well. The zinc and copper plates are united by slips of copper, and placed so that each pair encloses a partition between them, and that each cell contains a plate of copper and a corresponding one of zinc. The plates again are connected together by a slip of baked wood, so as to allow of their being let down into the trough or lifted out of it, simultaneously. Such an apparatus is called the *trough battery*. It admits of any number of these troughs being conjoined. This is done by connecting the extreme plates with slips of copper, taking care to preserve throughout the whole series the same order of alternation in the plates, by connecting the zinc end of one battery with the copper end of the next. The battery belonging to the Royal Institution is of this description. It consists of 200 separate parts, and each part is composed of 10 pairs of plates, and each plate presents a surface of 32 square inches; the whole number of double plates is therefore 2000, and the aggregate surface 128,000 square inches.

This construction was originally suggested by Dr Babington, as an improvement on Cruickshank's battery. This last is simply a long trough divided into cells, by means of partitions formed with plates of zinc and copper soldered together by their flat surfaces, and fixed into grooves made to receive their edges into the sides and bottom of the trough: the plates of course being so arranged, that all the zinc surfaces occupy the same side of the cells, and all the copper surfaces the other. The arrangement brings only half the amount of metallic surface employed into action, and this, together with the difficulty of making the joinings of the cells water-tight constitutes its inferiority.

As it was found that a more powerful current can be obtained by opposing a surface of copper to each of the surfaces of a plate of zinc in contact with an oxidating fluid, Dr Wollaston suggested the extension of the copper plate so as to accomplish this in the way shown in the annexed figure, (which is an edge view of the two plates.) This suggestion has been extensively adopted; but Mr Hart of Glasgow has further improved upon it, and makes the copper plate itself into a cell, to retain the exciting liquid, thus dispensing with a trough altogether. To accomplish this, nothing more was necessary than to join the edges of the double copper plate of Wollaston's battery. This is readily done by cutting a sheet of copper into the form shown in Fig. 7, and afterwards folding it up as seen in Fig. 8, and grooving the seams.

*Fig.* 6.

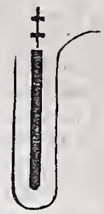


*Fig.* 7.

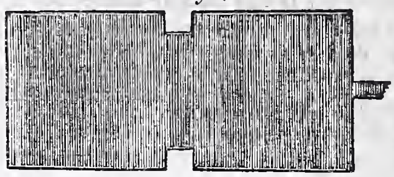
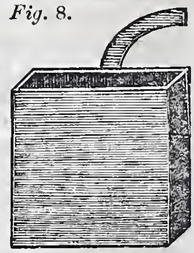


*Fig.* 8.



A small tail of copper is left for the purpose of connecting the cell with the zinc plate in the adjoining cell, as shown in Fig. 9, which represents a section of a portion of the battery. An isolated

*Fig.* 9.

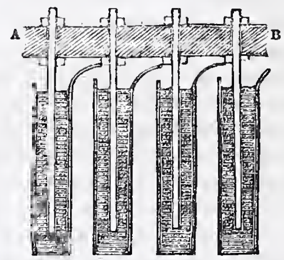
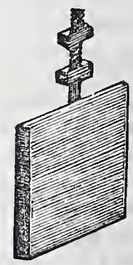


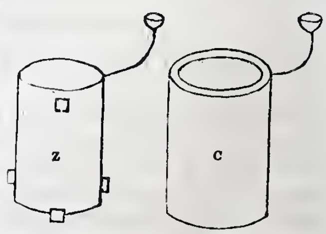

*Fig.* 10.



zinc plate is represented by Fig. 10: it has a piece of screwed brass wire cast in the top of it, for the purpose of suspension, the screw passing through the cross bar of wood A B where it is firmly fixed by means of two screw-nuts, as represented. The bar of wood must be previously well baked and varnished. When the battery is to be used, it is dipped into a trough containing the acidulous liquor, and brought out with all its cells full. It is also provided with short bars passing at right angles through the bar A B; these are for the purpose of suspending the battery while in use, in a suitable wooden frame, the extremities of the bars resting upon the top rail of the frame.*

A very useful modification of this construction of battery is shown in the annexed figures. C is a vessel of any size thought proper, composed of two cylinders of sheet copper, placed one within the other, and closed at the bottom to contain the exciting liquid; Z is a cylinder of zinc without bottom, made to pass into its place between the cylinder forming the receptacle C. It has a few bits of cork attached to it to prevent it from coming into metallic contact with the sides of the receiving vessel. The apparatus is usually provided with little cups, soldered to the conducting wires: these are for the reception of a minute portion of mercury, into which other wires may be placed when the current is to be conveyed through a galvanometer electro-magnetic machine, &c. A further improve-

*Fig.* 11.




* This form of Wollaston's Battery is described very fully in the Edinburgh Journal of Science, vol. iv. p. 19.

ment on this battery may be made by constructing it on the plan of Professor Hare's calorimotor.

Professor Hare's revolving battery is simply a modification of the common trough battery: the apparatus is conjoined with a second trough, into which the charging liquid is put, and the troughs being joined so that a change of position of the two causes the liquid to flow into the trough containing the plates.

About five years ago, Mr J. Young, late of Glasgow, published an account of his improved voltaic battery, now commonly preferred for experiments of a strictly chemical kind, as the decomposition of water and of saline solutions. The following is the description published by the author in the *Philosophical Magazine*:—

"The sheet copper and sheet zinc to be used in this battery are first cut into long ribands, of the breadth which it is intended to give the plates. Suppose the ribands two inches broad; both the copper and zinc ribands are then divided into lengths of five inches, and a portion cut out as in fig. 12. The slip is thus divided into two squares of two inches each, which are connected at A, and a piece is left projecting at B. The zinc and copper sheets are cut up exactly in the same way. Fig. 12 therefore

*Fig.* 12.

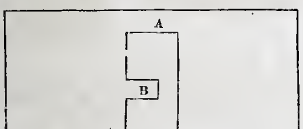



*Fig.* 13.

represents either a single zinc or a single copper plate. The plate is then bent at A, and presents the appearance represented in fig. 13. In fig. 14, we have two plates, one of copper C, and the other of zinc Z, which are exactly alike in form, but are placed differently, as shown in the figure. Thin projecting parts B B are soldered together, and this is the only metallic communication between them which is allowed to exist. Fig. 14, there-

*Fig.* 14.

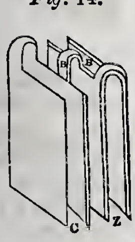
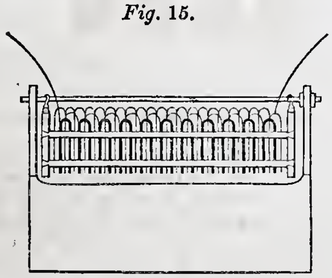



*Fig.* 15.



fore, is only one copper and one zinc plate, or it is one pair of plates. Each pair is made up in the same way. In arranging a number of pairs to form a battery, they are interlaced so that a copper square comes in between each couple of zinc squares, and a zinc square between each couple of copper squares. It is easy to see how this arrangement can be made, when the plates are in the hand, though it is difficult to describe it. At the positive end of the battery there is a single copper plate, which is soldered at the top to the last double copper plate, as seen in fig. 15; which figure represents twelve pairs properly arranged, and also the manner in which they should be fitted up and kept steadily apart in a wooden frame. This frame consists of two cross-bars, in front, and the same behind, dovetailed into solid ends. The channels in the cross-bars, for the reception of the edges of the plates, are formed by placing the four cross-bars together, and sawing a little way into one side of them all, every eighth of an inch or so in their length, so as to form a set of parallel grooves. We have by means of this frame a much greater security that no metallic contact will occur between contiguous plates, than when they are separated by wedges of cork, as in Dr Hare's construction, which may slip out.

"The frame and plates are introduced into a trough, which may be of wood or stoneware, containing the exciting liquor. Dr Hare's revolving arrangement of the two connected troughs may be adopted for this battery, although we have been led to give a preference in practice to a single trough to contain the frame. To the solid ends of the frame are attached two cords, which are fixed to two pulleys, on which they are wound up, on turning a winch, by which means the frame and battery can be raised out of the fluid, as represented in fig. 15. If the axis (a stout wire) on which these pulleys are fixed can be moved a little backward and forward on its bearings, it is easy, by means of a little projecting peg, which fits into a hole in the side of the pulley, to fix and support the frame in a position above the trough, and out of the exciting fluid, when that is desirable. But the form of the trough to contain the frame and plates may be varied according to the object in view, or the purposes to which the battery is to be applied.

"In comparing a battery of the form described above, either with Dr Hare's or any of the other forms in use, it is to be remembered that the plates or elements of the battery are all of double the size they appear to be, or that in this construction you have half the number of pairs, but each of double the dimensions of a pair in any of the old batteries having the same appearance.

"A small battery of this construction, containing twelve pairs, of two inches breadth, of plates the size which we have taken above as an example, may be contained in a trough eight inches in length, and will evolve, when its terminal wires are soldered to a Faraday's volta-electrometer, six or seven cubic inches of the mixed gases in three or four minutes, with a charge of half an ounce of sulphuric acid and half an ounce of nitric acid, in twenty-four ounces of water, (all by fluid measure,) and is therefore amply sufficient to demonstrate the decomposition of water on a considerable scale.

"It is proper to use the thickest sheet zinc which can be had, in the construction of the plates, although the thinnest sheet copper will suffice, from its being so well supported. When the zinc plates are worn out, the cross-bars may easily be pulled out of the solid ends, and the elements of the battery separated. New zinc plates being soldered to the old coppers, the whole may again be quickly rearranged in the old frame."

This battery may be constructed of any size; but it is to be observed that when the object is to obtain *intensity*, the number of elements, that is, pairs of plates, is to be increased; and when *quantity* is wanted, the size of the plates is to be increased.

The amateur may find a difficulty in soldering the straps of zinc and copper together. The difficulty consists in tinning the zinc. This, however, is easily effected by filing the part smooth, wiping it over with a little muriate of ammonia (sal-ammoniac), or dilute hydrochloric acid (spirit of salt), and then dipping it into a ladle of melted tin free of oxide. The oxidation of the tin is again prevented by placing a little tallow on its surface.

Every galvanic battery, of the sort noticed in this article, should immediately, after a series of experiments, be emptied of its exciting liquid, and have the plates well cleaned by washing in water, and wiping with a cloth. If this be not attended to, the plates will soon become covered with oxide at the expense of the metals.

## ON THE DISTINCTIVE CHARACTERS OF ANIMALS.

The objects of the material world were long considered as arranging themselves naturally into three grand divisions, or *kingdoms*, as they were called; the animal, the vegetable, and the mineral. Closer attention, however, and a more careful study of the qualities and actions of the various bodies composing these kingdoms, lead us to conclude, that the first two have much in common, and consequently, that a twofold division suffices to comprehend the whole of the objects in nature. These are the *inorganic*, or lifeless, and the *organic*, or living; the first embracing minerals, fluids, gases, and the various forms in which dead matter presents itself to our observation; the second including vegetables and animals.

The *organic* and *inorganic* kingdoms of nature are distin-

guished from one another by many strong features of difference; first, in reference to their general physical qualities, external form, size, and chemical composition; and secondly, in regard to their capacities for action.

The *forms* of the objects composing the inorganic world are *indeterminate*, when considered in *masses*, but are reducible to a few simple crystalline shapes when regarded in their *parts*. The cube, the hexahedron, the prism, and so on, are the elementary forms of the inorganic world; plane surfaces and straight lines, uniting under different angles, are the circumstances which give them their characteristic and individual shapes.

This is very different from what we see in the world of organization. From the lowest to the highest of living beings, the shape is *determinate* for the individual, not only as a whole, but even in as far as each of its parts is concerned. Instead of being bounded by angles and straight lines, like the objects in the inorganic kingdom, those of the organic are mostly rounded in their forms, or they are branched or jointed, or made up of several parts, which vary according to the offices they have to perform to one another, and to surrounding objects. Neither do they consist of homogeneous parts like minerals, but are made up in general of heterogeneous parts; in plants, we have roots, leaves, branches, and flowers; and in animals we have muscles, veins, bones, and a great number of organs, each itself reducible into a variety of other simpler parts or elements, which are called tissues.

The organic world also presents an immeasurably greater variety of forms than the inorganic; limestone and basalt are similar in their forms all over the world, whereas the myriads of animals and vegetables that cover the earth differ to infinity from each other in their forms and physiognomies.

Neither is there less difference between the inorganic and organic kingdoms in the quality of *size*, which, in the first, is perfectly *indeterminate*, being greater or less, simply as the constituent molecules happen to be congregated in larger or smaller numbers. The size of organized bodies on the contrary is *determinate;* every animal, every vegetable, has a particular stature, a certain bulk, which is that of its species, and is confined within narrow limits.

In their *chemical composition*, organized and inorganized bodies present numerous and striking points of dissimilarity. The chemists of our day enumerate no fewer than 52 elementary or simple substances, besides the three which cannot be confined, light, heat, and electricity. All of these are met with in the inorganic or mineral world; but only 19 of them have been detected in the composition of organized or living bodies.*

The *elementary particles* or *molecules*, entering into the composition of organized and inorganized objects, also differ in their *essential form*. Examined by the help of the microscope, the parts of all organic beings are found to be made up of globules, either spherical, or more or less oval or flattened. Nothing of the kind has yet been detected among inorganic bodies. Angular particles, separable to infinity into others of a like shape, are the elements of composition in minerals.

The aggregation of the organic molecules into a variety of *tissues* and peculiar *organs*, forms another essential feature of difference between the organized and inorganized kingdoms. As minerals manifest no variety of phenomena analogous to those of life, and so require no diversity of constitution in their different parts, they are consequently homogeneous. In animals and vegetables, on the contrary, the constituent molecules always form *tissues*, the fibres of which cross, or interlace with one another; in no living thing do we observe anything like what is called the cleavage in minerals, a capacity of being split up in several different directions.

From this it comes, that minerals are as complete in their parts as in their masses; the minutest fragment of marble has all the properties of this substance, as much as though it were a mountain. Organized beings, on the other hand, consist of a number of organs, whose united actions constitute the peculiar vitality of each being, and if any individual part be removed or destroyed, the being to which it belongs is thereby rendered imperfect.

Considered with regard to their *duration*, the objects composing the organic and the inorganic would differ essentially. In the former, this period is *determinate* and *definite*, and although it varies greatly, it depends in a great measure on circumstances inherent in the individual—in the latter it is *indeterminate* and *indefinite;* and when the objects composing it cease to be, it is generally in consequence of circumstances external to themselves. Organized beings exist for a limited time, in opposition to many of the laws both of chemistry and of physics; while inorganized beings exist indefinitely, and only in consequence of their agreeing with the whole of these laws. Organic beings continue to exist in consequence of a kind of reciprocal action with external things, and especially by virtue of an incessant change and renewal of their constituent particles. The very condition of existence of an inorganic body is its remaining at rest; any new action between its particles themselves, or between them and others external to them; any addition to, or subtraction from its component parts, implies the destruction of its individuality.

In the organic world, new beings arise from the actions of beings already existing, which have the wonderful power of producing others similar to themselves; and this in virtue of an especial power residing in each organized being individually. There is nothing like this faculty of *procreation* or *generation* in the inorganic world. When a new crystal is produced, it is necessarily at the expense of one or more that have previously existed, by a combination of the elements of them; *destruction* is here a necessary preliminary to *production*, and the process is simply one of re-combination, not of formation or creation. Neither in the re-combinations of inorganic bodies do we find that the new forms are always necessarily the same as those which preceded them; while among organized beings, nothing is more fixed and certain, than that the form of the new being shall resemble that of the one which gave it birth.

There is yet another distinction which may be mentioned; that while in inorganic bodies the composition is quite determinate; in organized beings the individuals of a species may present lesser differences, or modifications. These are designated by the terms *temperament*, or *constitution*.

But besides this form, size, composition, duration, and mode of origin, organic and inorganic bodies differ in their mode of existence. All organized or living bodies are *active;* every creature which has life performs actions, or exhibits forces by which its own existence is continued, and by which it participates in the various phenomena of the universe. The whole of the actions of organized beings are the effects of the agent which is denominated *life*, and of the laws which this agent originates.

Let us briefly examine in succession the various actions by which bodies *originate—continue their existence—undergo the modifications* which they exhibit during their existence—and by which they *come to an end* or *die*.

Unorganized bodies, minerals for example, commence their existence from the instant that circumstances exterior to themselves detach them from the mass of some other mineral, precipitate them from a state of solution in a fluid, or bring their elements into a position in which they can combine. In all this, it is evident, there is nothing like *generation*, as is seen in organized bodies, which, both vegetables and minerals, commence from one atom or molecule, deposited by a being similar to themselves, which has existed before them. Vegetables spring from seeds, animals from eggs. Organized beings therefore, are *engendered;* their existence is a consequence of the existence of other beings like themselves, and in this succession they depend one upon another. Minerals on the other hand have no powers of reproduction; they are individually in a state of perfect independence, and if at any time they originate another mineral, they by so doing cease themselves to be.

In the mode in which organic and inorganic bodies *continue their existence*, there is also a striking dissimilarity. In the inorganic world we observe no actions tending to preserve the individual, except those which have presided over its formation; it continues to exist through the continuing agency of the affinities and attractions which called it into being. Animals and vegetables, on the contrary, have special powers for their preservation superadded to those by which they have been created. Inorganic bodies exist through the absence of all change in their interior; organized beings exist only by means of change: there are two processes, one of renewal, the other of decomposition, perpetually going on within them; they are continually appropriating from bodies exterior to themselves a quantity of matter, which they have the singular power of converting into their own

* Oxygen, hydrogen, carbon, azote, phosphorus, sulphur, iodine, bromine, chlorine, fluor, silicium, aluminum, magnesium, potassium, odium, calcium, manganese, iron, and copper.

proper substance, and have at the same time, the power of withdrawing portions of the matter which already forms them, and rejecting them from their interior, as no longer fitted for their preservation. Vegetables, by means of their roots and leaves, draw from the earth and air, materials fitted for their nourishment; at the same time that they throw off, especially by their leaves, a portion of the matter which had been absorbed, as being superfluous, or improper to enter into their composition. In the same manner, animals appropriate to themselves various amounts of matter in the shape of atmospheric air, and food, from which they prepare a fluid, proper for their maintenance, while they throw off the portions which are noxious or not required, under the form of excretions. Organized bodies are thus maintained, in one word, by a process of *nutrition*.

The *modifications* undergone by organized and inorganized bodies are peculiar and characteristic in each class. In the first place, modification or change is no necessary condition to the existence of an inorganized body. A mineral in a state of complete isolation, if that were possible, might remain unchanged to all eternity; but a plant or animal cannot be conceived as existing for a moment, without connexion with surrounding objects, and without undergoing change. A mineral, in the instant of its formation, acquires all the properties that distinguish it throughout its whole subsequent existence; but in plants and animals, we observe a series of changes, denominated *ages:* they commence their existence, they increase in size, they attain maturity, and they decline, and ultimately die.

Whatever has a beginning, has also an end. But the modes in which organized and inorganized bodies cease to be, are extremely different. A mineral comes to an end, when the affinities that combined its constituents, and the cohesion that held its particles together are overcome. Its destruction is effected by agencies external to itself, by the action of other bodies, and by circumstances over which it has no control. The destruction of a mineral is therefore neither *necessary* nor *spontaneous.*

Very different is the case with animals and vegetables; as their continuance depends on the process of nutrition, their end hangs upon the cessation of this act; and as the machine of their organization is calculated to endure only for a season, their *death* or destruction is both *spontaneous and necessary.*

From this review of the distinguishing peculiarities of organized and inorganized bodies, it appears that organization implies vitality, and that organization and life are inseparable conditions. I do not mean to say that they are synonymous terms, only *organization* is the mode of structure proper to living beings; *life* is the series of actions which they exhibit.

As a general observation, the material constitution of vegetables may be said to be *simpler* than that of animals, at least this statement holds good of the more perfect of both kinds.

No distinguishing feature of either class is derivable from general diversity of *size.* Between the microscopic lichen and the gigantic oak—between the animal found in a drop of putrid water, and the mighty whale—plants and animals of every intermediate magnitude are discovered. Neither is there much to be said of the differences which animals and vegetables present in their *forms.* Only, as a general law it may be remarked, that in animals, we generally find a number of limbs proceeding outward from a central part; while in vegetables, we have a tendency to division and sub-division into branches.

All organic bodies are made up of solids and fluids; but with few exceptions, the proportion which the solid bear to the fluid parts, is much greater in vegetables than in animals: besides, the fluids contained in the bodies of the higher animals, the blood, chyle, urine, bile, seminal fluid, &c., have in general very different characters from the sap of the more perfect vegetables, and even from the secretions which are peculiar to some of them.

The solids which enter into the composition of each class, are still more widely dissimilar both in their outward and in their intimate characters. The most simple vegetables, the *cryptogamia,* consist of a homogeneous tissue, forming rounded or oblong cells, filled with fluid; and it is only when we ascend to the flowering vegetables that we find any distinction of cellular and tubular tissue, the whole texture of the plant being surrounded by an integument or bark.

The tubular tissue, or vessels, of vegetables, occurs in two distinct forms—sap vessels and nutrient vessels. The sap vessels rise among the woody fibres, ascending into the leaves, the flowers, and the fruit. The juice which these vessels contain, is altered in the leaves by exposure to the air, so that the leaves may with great propriety be considered the lungs of vegetables; and the proper nutrient-vessels then descend in the bark, and penetrate to every part, distributing the essential juice, or what may be called the blood of the plant.

The tissues which enter into the composition of animals, are much more numerous than those of vegetables. The cellular, the vascular, the nervous, and the muscular, are the most universally distributed; while the tendinous, the bony, the cartilaginous, and the horny, are less uniformly diffused among the species composing the animal kingdom.

The *cellular* is the tissue most universally met with in animals: it exists in them from the very highest to the very lowest. Its general appearance is that of a soft, homogeneous, whitish, semitransparent, extensible, and slightly elastic substance. It is permeable by air and liquids, and when distended by these, presents a series of continuous cells, or cavities, from which the tissue has received its distinguishing title. The cellular tissue is dispersed abundantly through every part of the animal body; it enters as a principal element into the composition of many other tissues; it pervades the innermost parts of almost all organs, and in a modified shape forms a covering for them externally; it may be said to constitute the frame-work of the organs generally, supporting them in their particles as it does in their masses; it connects them together also, includes and accompanies the blood-vessels that supply them with nourishment, fills the intervals betwixt them, and establishes continuity between every part. The interstices of its filaments are during life moistened by a thin serous liquid, which sometimes appears as a vapour, on their being laid open.

The cellular tissue forms the various membranes of animal bodies: the skin, the fibrous, mucous, serous, and synovial membranes, all appear to consist of this tissue in different states of condensation.

The *vascular* is another tissue extensively distributed among animals. Three modifications of the vascular tissue have been reckoned by anatomists, in arteries, veins, and lymphatics.

The *nervous* is a third tissue peculiar to animals. It may be held as the tissue most distinctive of the high classes of organized beings, as through its means they exhibit almost all the faculties which place them so far above vegetables in the scale of creation. Nervous tissue is a soft, whitish substance, arranged in globules, and connected by extremely delicate cellular tissue. It is arranged into central masses, called in the higher animals the *brain and spinal marrow,* and cords, forming communications between these and the different organs of the body. The central masses are the seats of power, sensation, and intellect; and the communicating nerves convey intelligence from the extremities to the brain, and commands from the brain to the extremities.

The fourth tissue peculiar to animals is the *muscular.* In several of the lowest grades this cannot be demonstrated, although from the power of motion we are led to infer its existence. This muscular tissue consists of fibres, whose chemical constituent is called *fibrin.* Its peculiar characteristic is its power of contracting or becoming shorter, and of relaxing again to its former length.

The fifth tissue which prevails among animals is the *fibrous.* This is of two kinds, the tendinous and the ligamentous. These consist of parallel and interlacing fibres, of a white colour and pearly lustre, of great strength, and little elasticity, subservient to the muscular tissue and the power of motion.

The sixth tissue peculiar to animals is the *bony* or *osseous.* This composes the frame-work or skeleton, which gives their form and place to all the other parts entering into the formation of the body. The essential organic element of bone is a cellular network, within the meshes of which certain salts of lime are deposited, in order to give them hardness and solidity.

The *cartilaginous* is generally reckoned as the seventh elementary tissue of animals, but is very similar to the osseous; the bones being cartilaginous at first, and the cartilages having a tendency in old age to be converted into bone.

The *fibro-cartilaginous* tissue is an interesting modification of the fibrous. The fibro-cartilages enter into the formation of joints, and are very strong and elastic.

The calcareous coverings of insects and shellfish have uses

corresponding to those of the bones, the muscles being attached to their inner surfaces, besides serving as strong organs of protection.

The last tissue which I shall mention as peculiar to animals is the *horny*. It forms the cuticle which covers and protects the delicate surface of the true skin; it is prolonged into the nails, claws, and hoofs, and the horns of those which are provided with such appendages.

Nothing analogous to these tissues can be discovered among vegetables. In animals, besides occurring in various parts in their simple forms, they are also compounded into numerous *organs*, as the lungs, liver, stomach, kidneys, and so forth, nothing corresponding to which exists among plants.

Besides the solid parts of animal bodies, there is a great variety of *fluids*, for various important purposes. First, there is the *blood*, a highly nutritious fluid, which is circulated through the whole body, and from which all the other fluids are prepared. These are the saliva, gastric juice, pancreatic juice, and bile, all to assist in digestion; the sweat and the urine to carry off the worn-out parts of the body, and a peculiar fluid, the spermatic, prepared for a means of continuing the species. Fluids bearing a distant resemblance to only one or two of them aro found among vegetables.

Let us now turn to the *special manifestations of life* in the two great divisions of organized beings; and let us consider them in the following order; namely, their *origin* or *reproduction*, their *nutrition* or *self-preservation*, their *ages* or the *changes* undergone during the period of existence, and lastly, *death*, or its termination.

Vegetables and animals alike derive their *origin* from a birth or procreation accomplished in two different modes, either without or with the concurrence of opposite sexes. When organized beings are produced without sexual means, the parent either divides into several pieces, each of which becomes an independent individual, or throws out buds from its surface, which become detached in due season, and are able to exist by themselves. When again, they spring from the concurrence of sexes, two sets of organs are required for the operation—one denominated *male*, supplying a fecundating matter, the other called *female*, furnishing a germ, which after its impregnation by the male secretion, undergoes a series of evolutions that end in the issue of an individual resembling the parents, and fitted by its own acts to preserve itself and to perpetuate its species.

Both of these modes of reproduction are common to vegetables and animals. *Confervæ*, among vegetables, and *polypi*, among animals, exhibit the first mode, almost without a difference. Buds or sprouts arise from the surface of both, and here for a time, acquire a certain size, and are detached to become independent beings. Besides, the polype being cut into several pieces, gives origin by each part to a distinct polype, just as the cuttings of many plants, if set in the earth, take root, and become new plants.

The second mode, by the concurrence of two sets of organs which are male and female respectively, presents in the two divisions many distinguishing circumstances. The most striking are these; that while in vegetables, the whole of the acts which constitute reproduction are performed without the will, or even the consciousness of the individual, but irresistibly and necessarily, as a consequence of its growth; they take place among animals consciously, and are left, in some particulars at least, to their will.

*Nutrition* is a series of actions depending on the law by which every organized being continues its life through a perpetual renewal and decomposition. It is therefore a twofold process, consisting of the appropriation of new nourishing matter, and the rejection of the old and worn-out particles which have already served their time in the economy. Nutrition is a very comprehensive term, and includes the whole of the vital acts by which the individual continues its existence,—namely, among the higher classes of creatures possessing life, the assumption or taking in of aliment; its preparation by the processes of digestion and respiration; the distribution of the nutritive matter by means of a circulation; its conversion into the solid and fluid parts of the individual; and finally the rejection of the worn-out particles by certain excreting organs. Let us now contrast these functions as they manifest themselves in each of the two great divisions of the organized world.

1. *Assumption of aliment*. The earth and the atmosphere, the carbonic acid and water which they contain, are the sources whence vegetables derive their food. There they find aliment ready prepared for their use, consisting however, not of the inorganic earth and water; but of the decomposed parts of former organized beings. The food of animals is much more composite, and is taken under very different circumstances. In vegetables it is received from the external surface, with which the nourishing matter is in contact, while in animals, it has to be sought for, seized with organs contrived for the purpose, and conveyed into an internal cavity,—a stomach, or alimentary canal.

We do not find anything like a stomach in vegetables. In some of the very lowest of animals, the case is similar, and the nourishing fluid appears to penetrate by means of pores, and to be conveyed over the body, without ever getting into a central cavity. But in all animals, except those very lowest, we have this central pouch or stomach, communicating with the external world by a mouth, or at least by means of pores. Various accessory organs to the stomach are found among animals; organs of sense to guide them in the choice of food; teeth to bruise or masticate it; glands, by which juices, which exercise a chemical influence on it, are secreted; lacteal vessels by which the chyle or nourishing fluid formed from the food is carried into the circulation; and an opening at the further end of the alimentary tube by which the particles containing no nourishment are expelled.

2. *Respiration*. The circulating fluid, it has already been stated, requires to be exposed to the air, both in animals and vegetables. The chemical changes are different however, in the two cases; in animals, oxygen is absorbed, and carbon is given off; while in vegetables, carbon is absorbed and oxygen is given off. In plants, respiration is carried on by the leaves; in animals, by *spiracula*, *tracheæ*, or *windpipes*, by which air is permitted to traverse their bodies, or by certain organs set apart specially for the purpose, which we call *lungs*.

3. The nourishing juices thus prepared have now to be distributed; and this is done by means of sets of tubes ramifying over the system. I have already stated that the sap which passes up through canals in the woody fibres of plants, is elaborated in the leaves, and is distributed over *their* systems by vessels in the bark. The power by which the motion of the sap is produced is not satisfactorily ascertained. In animals, there is a sort of forcing-pump, called the heart, by which their nourishing fluid, the blood, is sent all over the body, through a set of tubes called arteries; and that part which is not required, is returned to the heart by other vessels called veins, to be again circulated. There are, however, some parts of animals where we find the circulation going on, to which the force of the heart can scarcely extend, and indeed in some animals where we can perceive no heart at all. This circulation permits of the nourishing fluid which has been obtained from the aliment by the process of digestion, being carried into any part of the system, and between the more intimate particles of the structure. There is a power residing either in the blood-vessels, or in the fluid which they carry, by which it becomes deposited out of the vessels, in those parts of the body which are in need of repair, or of increase; and becomes of the same nature as the tissues with which it is brought into association. This part of the process is properly called *assimilation*.

4. Besides the watery exhalations, and the oxygen thrown off by the leaves of vegetables, many other substances are excreted by them; and by peculiar glandular apparatus which we are at no loss to discover. Thus from the flowers of vegetables are thrown off many substances, whose odours proclaim them to be different; the fecundating matter which the anthers shed on the pistil are *secreted;* and so are the various gummy, balsamic, camphoric, and oleaginous products which we find in many tribes. In animals, a much longer list of secretions may be enumerated—the limpid fluids that moisten various cavities in the body, and all the exposed surfaces,—those that are subservient to digestion,—those that are laid up as reservoirs of nutriment,—those that carry off the worn-out particles,—those that minister to the reproduction of the species, and to the nourishment of the newly-born being. In animals above the very lowest, the process of secretion is performed by *glands*—peculiar apparatus in which numerous blood-vessels end, whose blood furnishes the material for the secretion of the new fluid.

In addition to these various products, both animals and vegetables possess the power of disengaging heat, light, and electri-

city. Into a dissertation on these subjects, which belong rather to the chemist than the anatomist, I do not think myself called upon to enter.

5. The principal changes which we see taking place in the organic world, in addition to those which have already been referred to, under the head of nutrition, are the motions consequent on sensation. These are scarcely, if at all participated in, by vegetables. But in animals, we have an organ more or less developed, which is the centre *to* which sensations are brought, and *from* which the power is given to perform their various actions. We have also cords of communication passing from this centre, to all parts of the body; and in the more perfect classes, we have special senses superadded, for distinguishing certain qualities in external objects.

6. Finally, both animals and vegetables have a natural period of existence, which they cannot pass. Although they grow for a time by throwing off their old particles and taking on new, they do not always maintain the same freshness; but pass through certain changes, according to the time they have lived, denominated *ages*, and at length die; and this termination comes as surely to the ephemeral gnat, which is born with the summer's sun, and perishes with the evening twilight; to the conferva which appears green on the stagnant ditch, and vanishes with the introduction of the running stream; to the oak which raises its head to the clouds, and strikes its roots deep into the earth; and to man, the lord of the creation, whose days at almost their utmost span, are limited to threescore years and ten.

## STRENGTH OF THE TEETH OF WHEELS.

In the rules now in general use in calculations for the strength of wheels, the teeth are considered as beams; the breadth of the wheels, the distance from the root of the tooth to the point, and the thickness of the tooth being supposed to represent the breadth, length, and depth of the beam.

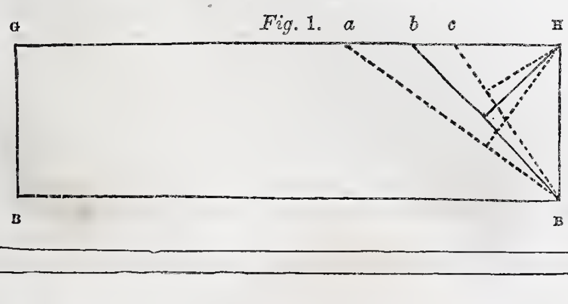
If the teeth of wheels could be made so mathematically correct in form, and in fixing, the wheels adjusted to each other with such a degree of nicety; and could they at all times be caused to remain so when they are at work, so that each part of the breadth should bear its proportionate share of the whole strain, then the above-mentioned rules would be quite correct, and no better could be desired. But to construct a wheel absolutely without any deviation from truth is an impossibility, and were it not so, the unequal wearing of the brass steps in which the shafts revolve, and the springing of the shafts themselves, are sufficient to throw the wheels out of truth, and cause the teeth to bear harder on one point than another.

Every portion of a piece of machinery, or in fact, of any structure whatever, should be made of such a strength as not only to sustain, uninjured, the greatest stress that is likely to come upon it in the ordinary course of things, but also to withstand that stress acting upon it in the worst possible direction, or that in which the structure is capable of offering the least resistance. Upon this principle, the teeth of a wheel should be made sufficiently strong to support the intended pressure acting, as we have seen it do occasionally, on the extreme corners of the teeth, their most vulnerable point.

In the rule before mentioned, the whole breadth of the teeth, whatever that breadth may be, is considered as affording strength; but it may be proved that no effectual strength is gained in making the breadth more than twice the length of the teeth, and therefore the rule, as far at least as regards its practical application, is formed on erroneous data.

Let G H B B (fig. 1.), represent the side view of one of the teeth of a wheel; H B being the height or length, and B B the

*Fig. 1.*

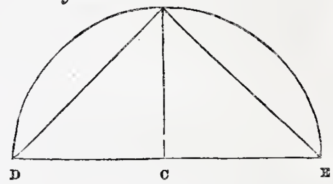



base or breadth of the tooth. Now, if a force sufficiently great to break the tooth act on one of the corners H, the fracture, provided the base exceeds twice the height, will not take place along the base B B, but along the line B *b* or a line parallel to it; these being lines of less resistance, under the circumstance of the pressure being applied at H, than the root or base of the tooth B B.

The strength of beams of equal thickness is directly as their breadths, and inversely as their lengths; hence the strength will remain unaltered, whatever difference is made in the dimensions, if the proportion of the length to the breadth is preserved unchanged, and no difference made in the thickness; and therefore the fracture, in the case in question, will be along that line which, as a base, bears the least proportion to the perpendicular height from that base to the point where the pressure is applied. This least proportion will be when H *b* is equal to H B; the base *b* B will then be only double the altitude (or effective length of beam) H *h*. For it will be found that if a line be drawn from B to *a*, it will be more than double the altitude of the triangle B *a* H of which it forms the base, and the same thing will occur if the line B *c* is taken as a base.

To prove this in another and more direct way, suppose D C (fig. 2.), to represent any line cutting off a portion of the angle *h* in the preceding figure. From the centre C describe the semicircle D F E; it is evident that the longest line that can be drawn in the semicircle at right angles to the base D C E will be the radius C F; and as D C, C E, and F C, are equal to each other, so the chords D F and F E will be equal; and the base D C E will be twice the length of F C.

*Fig. 2.*




Therefore B *b* (fig. 1.), (or a line parallel to it) will be the line of least resistance, and the effective proportion of the breadth of the teeth can never exceed twice the length.*

Hence it is obvious that no additional practical strength is gained, by making the breadth of the teeth more than a certain ratio to their length, and this ratio has been shown to be 2 to 1, or, (under the modifying effect of the varying thickness of the tooth in its section,) very nearly in this proportion. It must not however be inferred from this, that it is useless to make the breadth any greater than this proportion; on the contrary, it is highly advisable that it should bear a much greater ratio than this, so that the wearing action, by being distributed over a larger surface, may not so soon reduce the thickness of the teeth, and thereby render the wheel too weak for its work. But in our calculations for ascertaining the dimensions necessary to give the teeth to enable them to resist any given force, this proportion only of the breadth should be introduced; because, as has been shown, this is all that constitutes their effective strength.

The strength of bars or beams is as their breadth multiplied by the square of their depth, and inversely as their length. And assuming this rule to be correct, if $a$ represent the known strength of a bar 1 inch long, 1 inch deep, and 1 inch broad; and if $w$ equal the weight required to be sustained by a bar, of which $x$ is the depth, and $b$ and $l$ the ratios of the breadth and length to the depth $x$; then

$$a : 1 :: w : \frac{b\,x^2}{l}$$

$$\text{when } x = \sqrt{\frac{l\,w}{a\,b}}$$

But we have seen that double the length is the only part of the breadth of the teeth that should be calculated upon.

* It has been assumed that the thickness of the tooth is the same at the point as at the root, but it is not so in reality, the section being of the annexed form; this, however, although it will make a slight alteration in the line of least resistance, will not alter the general principal, that there is a limit in breadth beyond which no strength is gained, nor will this limit differ very materially from double the length of the teeth.

Therefore $b = 2\,l$

$$x = \sqrt{\frac{l\,w}{a\,b}} = \sqrt{\frac{l\,w}{2\,a\,l}} = \sqrt{\frac{w}{2\,a}}$$

Hence it appears that when the breadth exceeds twice the length of the teeth (and it always does in modern practice), that both may be omitted in the calculation by simply making use of the coefficient 2 in their stead.

It has been well ascertained that, as a mean effect, a bar of cast iron one inch square, and one foot long, if fixed at one end and loaded at the other, will require a weight of 640 lbs. to break it. And $640 \times 12$ inches equal 7880 lbs. is the utmost weight a bar one inch square and one inch long, is capable of sustaining.

If the greatest dead weight the various parts of a well-proportioned steam-engine are able to carry, be compared with the greatest strain the steam pressure can exert upon them, it will be observed that the former is about ten times as great as the latter. Hence we may infer that, in common with other parts of machinery, the teeth of wheels should not be loaded to more than one-tenth of the ultimate strength of the material of which they are composed; and thus $\frac{7880}{10} = 788$ pounds, is the value of $a$ for cast iron in the preceding equations.

*The weight being given, to find the thickness of the teeth.*

Rule 1. Divide the weight acting on the wheel at the pitch line by 1576 (that is, twice 788), and the square root of the quotient will be the thickness required.

*The thickness of the teeth being given, to find the weight which they will bear without failing.*

Rule 2. Multiply the square of the thickness by 1576, the product will be the weight in pounds that may be sustained with safety.

Example. The greatest pressure on a wheel at the pitch line is 6000 pounds. Required the thickness of teeth necessary? $\frac{6000}{1576} = 3{\cdot}8$ and the square root of $3{\cdot}8 = 1{\cdot}95$ or nearly 2 inches. 1 horse power, the unit of force used in calculating machinery, is equivalent to 33000 pounds raised 1 foot high per minute. But this is the mean amount of force exerted; and as most prime movers are more or less variable or intermittent in their motion, any wheel transmitting this motion should be strong enough to bear its maximum force with safety. The excess of this maximum above the mean force will of course vary with the nature of the prime mover; but it will be an approximation sufficiently near the truth for general purposes, if this maximum is estimated at one-fourth more than the mean. Therefore $\frac{33000 \times 1\frac{1}{4}}{1576} = 26{\cdot}2 =$ the square of the thickness of a tooth capable of transmitting one horse power when the pitch line of the wheel moves through the space of one foot per minute.

*When the number of horses' power and the velocity of the wheel are given, to find the thickness of the teeth.*

Rule 3. Multiply the number of horses' power by 26·2 and divide the product by the velocity of the circumference of the wheel in feet per minute, the square root of the quotient will be the thickness of the teeth in inches.

Example. Required the thickness of teeth equivalent to 10 horses' power, the wheel moving at the rate of 360 feet per minute.

$$\sqrt{\frac{26{\cdot}2 \times 10}{360}} = \frac{\sqrt{26{\cdot}2}}{6} = {\cdot}85 \text{ or nearly } \tfrac{7}{8} \text{ of an inch.}$$

Again, $\frac{26{\cdot}2 \times 12}{3{\cdot}1416} = 100$ nearly, which is the square of the thickness of the teeth of a wheel 1 inch diameter, and 1 horse power when making 1 revolution per minute.

*The diameter of the wheel, its number of revolutions per minute, and number of horses' power being given, to find the thickness of the teeth.*

Rule 4. Divide 100 times the number of horses' power by the number of revolutions per minute, multiplied by the diameter of the wheel in inches, and the square root of the quotient will be the thickness in inches.

Example. Given the diameter of a wheel 2 feet, the number of revolutions per minute 30, and 8 horses' power. What should be the thickness of the teeth?

$$\sqrt{\frac{8 \times 100}{30 \times 24}} = 1{\cdot}05 \text{ inches thick.}$$

*When the thickness of the teeth, the number of revolutions per minute, and diameter of the wheel are given, to find the equivalent power.*

Rule 5. Multiply the square of the thickness by the diametor of the wheel in inches, and by the number of revolutions per minute; divide the product by 100, and the result will be the number of horses' power required.

Example. There is a wheel 4 feet 8 inches diameter, which makes 35 revolutions per minute. What is the greatest power that should be transmitted by it, the teeth being 1 inch thick?

$$\frac{56 \times 35 \times 1^2}{100} = 19{\cdot}6 \text{ horses' power.}$$

The following is the rule generally made use of.

Rule. Multiply the breadth of the teeth by the square of the thickness, and divide the product by the length; the quotient will be the proportional strength in horses' power with a velocity of 2·27 feet per second.

Let us compare this with the 5th rule, by working the last example according to this rule, supposing the breadth of the teeth to be $5\frac{1}{2}$ inches, and their length $1\frac{1}{2}$ inch.

$$\frac{5.5 \times 1^2}{1{\cdot}5} = 3{\cdot}7 \text{ horses' power at a velocity of } 2{\cdot}27 \text{ feet per second.}$$

$$\frac{56 \times 35 \times 3{\cdot}1416}{12 \times 60} = 8{\cdot}55 \text{ feet per second.}$$

$$\text{and } \frac{8{\cdot}55 \times 3{\cdot}7}{2{\cdot}27} = 14 \text{ horses' power nearly,}$$

The strength, as given by the last rule, is only equivalent to 14 horse power, whilst according to the 5th rule it would be as much as 19·6 horses' power; but that the results given by the latter are considerably within the bounds of safety is sufficiently proved by the fact, that the dimensions and velocity of the wheel in the example are those of a wheel which has been at work nearly two years, during the whole of which time it has transmitted a power of 45 horses, and that too under the trying circumstances of the work done being of a very irregular nature, so much so indeed, as often nearly to bring the engine up; and although the teeth are much worn, and show that they are overloaded, yet there is no apparent symptom of failure.

The power assigned to the teeth of any wheel by the last rule is less than by the 5th, at all breadths below five times the length of the teeth; when broader than this proportion, it is greater.

## NATURAL PHILOSOPHY AND CHEMISTRY.

### CHAPTER VI.

#### ON THE SOURCES OF HEAT.

There is a question to which, in our preceding discussion of the properties and effects of heat, we have only casually referred. It is this: where is the abode of heat? whence does it proceed? From the illustrations already advanced, it is not difficult to answer, that it exists everywhere, and can be obtained from everything. We have seen that by diminishing the capacity of any body, whether solid, liquid, or gaseous, heat is evolved; and we therefore conclude, that it is present in all bodies, diffused throughout their substance, although imperceptible to our senses and our instruments. A gas when suddenly compressed, and a piece of iron when dextrously hammered, both give out heat. This, however, is entirely due to change of volume; "the particles being brought nearer to each other, there is less space than the heat can occupy—it is squeezed out, so to speak, and an elevation of temperature is occasioned; a quantity of heat having become sensible, which was before insensible." Closely allied to the development of heat by this mode, is the intense and unlimited amount of heat by friction. The action which takes place between a wheel and its axle, when left without oil, often develops heat sufficient to inflame wood near it. Two dry branches of a tree kept strongly rubbing against each other by the wind, have sometimes set a forest on fire; and it is well

known that certain Indian tribes, with a degree of dexterity which we do not possess, have so far applied observation to practical purposes, that they are in the habit of lighting their fires by the simple process of rubbing two bits of wood together. Similarly, the rope attached to a whale-harpoon, as it runs rapidly over the side of the boat, when the whale dives after it is struck, requires to have water constantly poured upon it to prevent ignition; and we have seen the cable of a ship, when drawn very rapidly through the hawse-hole by the falling anchor, produce there intense heat and smoke. Even two pieces of ice, when quickly rubbed together, melt at the surfaces of contact, showing that at least the heat necessary to liquefaction is evolved by the friction which takes place. The effect of friction in eliciting heat is indeed still more familiarly illustrated in the very common operation of rubbing the hands against each other in winter, to warm them.

In the familiar oase of the mutual percussion of flint and steel, the sparks consist of small particles of the metal struck off by the collision in a state of white heat. They burn in passing through the air, in consequence of a chemical action to be shortly noticed. The heated particles are equally produced when the collision takes place in a vacuum; but they are scarcely visible, as the combustion does not take place under these circumstances. In both cases, however, they suffice to ignite gunpowder, and to light tinder. The copious display of fire, elicited in sharpening a knife on a knife-grinder's wheel, is accounted for in the same way. Two pebbles, indeed, when rubbed together in the dark, give out light and heat; and we have again and again observed gleams and sharp scintillations of fire playing over the surface of a mountain torrent, when swollen and impetuous, and dashing the basaltic boulders in its bed against each other. It is, therefore, not necessary that the bodies should be of different natures, or possessed of any opposition of qualities to give out both heat and light by collision; and, it may be observed, that no change of the qualities of the minute particles which are broken off in a state of white heat by the blow, is discernible when they are cooled down to the atmospheric temperature.

A very remarkable circumstance attending friction as a source of heat is, that it is absolutely unlimited: so long as solid bodies can be made thus to act mechanically upon each other, heat is given out. In North America, for instance, where water power is very abundant, it is common to apply the surplus power of a water-wheel to make large plates of iron rub against each other; and the heat evolved is employed in warming the building in which the apparatus is placed. This is a practical experiment, and by far more satisfactory than that of Count Rumford for ascertaining the quantity of heat evolved by friction. This consisted in causing a blunt steel borer, three inches and a half in diameter, to be driven against the bottom of a brass cannon, seven inches and a half in diameter, with a pressure equal to the weight of 10,000 lbs., and, in that state, making it revolve at the rate of thirty-two revolutions a minute. In forty-one minutes 837 grains of dust were produced, and the heat "generated was sufficient to raise the temperature of 113 lbs. of the metal 70 degrees—a quantity of heat which is fully capable of melting six pounds and a half of ice, or of raising five pounds of water from the freezing to the boiling point." The experiment was repeated under water, and two gallons and a half of water at 60° were made to boil in two hours and a half.

M. Becquerel has of late made some very interesting experiments on the evolution of heat by friction. From these it appears that when a rough body is rubbed against a smooth surface of another, the latter becomes much hotter than the other. Thus, when polished glass is rubbed against cork, the first becomes hotter in the proportion of 34 to 5; ground glass becomes hotter than cork in the proportion of 40 to 7; and when silver and cork are similarly rubbed together, the first becomes hotter than the second in the proportion of 50 to 12. Conduction may have something to do with these differences; but it is obvious, from the relations given, that it does not afford a full explanation. Glass is a much better conductor than cork, but silver is still far superior in its conducting power to glass; yet the relation of the former is 34 to 5—that is nearly 7 to 1; and of the latter, the relation is only 50 to 12—that is $4\frac{1}{6}$ to 1.

From all these phenomena of the evolution of heat by friction, it is difficult to decide whether it is the result of a permanent alteration in volume—that is, a compression of the bodies which are rubbed together—or whether the vibrations of the particles themselves are to be regarded as the cause of heat. This is a subject to be hereafter considered; but in the mean time it may be observed, that although every change of volume is accompanied with some change of temperature, our command over the evolution of heat by compression is limited. As already remarked, we heat a piece of iron by hammering it; but it is equally true that it becomes less and less hot with every successive hammering; indeed every successive stroke of the hammer evolves less and less heat; and after a time the most violent blows produce no further elevation of temperature. This is accounted for on the supposition that the molecules cannot be made permanently to approximate more closely; and, although a slight instantaneous compression may take place, the quantity of heat disengaged is too small to be sensible, or is absorbed by the instantaneous expansion which succeeds. On the other hand, we have seen that the heat evolved by friction has no limits, but is supplied as long as the action is kept up.

There is a development of heat arising from molecular action, which is closely connected with the preceding. Thus, when water is poured upon a piece of limestone which has been subject to a white heat, there is, as every one knows, a large amount of heat evolved. The *lime-shell* swells and becomes hot—sufficiently hot to inflame wood—and ultimately falls down in fine dry powder. This is explained by saying that the water combines with the lime, forming what chemists call a *hydrate* of lime, and gives out, during the action, its heat of fluidity; it is this heat of fluidity, becoming sensible, which causes the remarkable elevation of temperature observed. This effect is not confined to lime as a base—the other earths, when similarly treated, evince the same power of solidifying water, and eliminating its heat of fluidity. And although we have not yet described an apparatus sufficiently delicate to test the fact, it is nevertheless true, that whenever any solid body is wetted by a liquid, heat is disengaged. This is particularly remarkable when a liquid is poured upon any insoluble powder, as upon pounded glass.

The fact here noticed is, perhaps, the first step towards an explanation of our great artificial source of heat—combustion. This, of all the phenomena in nature, whether contemplated in its beauty or in its terrors, seems, on first thought, altogether inexplicable. Indeed, even to the chemist, it is one of the most remarkable, one of the most important, and one of the least understood of all the phenomena in nature. Seen in its beauty, diffusing its cheerful influence over our parlour hearth, or beaming a steady light around from our lamps and chandeliers, it excites in us a feeling of pleasure, which we can only appreciate when we contemplate circumstances where its effects are wanting; and when it accidentally spreads from a focus, enveloping in sudden flame the objects around us, the apartment, the building, the town, or the forest, in which we are, consuming with deafening uproar everything in its progress, we behold it with feelings of terror. And this feeling rises into another name—it becomes a feeling of awe—when we witness the effects of this agency labouring within the bowels of the earth, first preparing, then urging up to heaven the volcanic eruption of flame and red-hot rocks, and vomiting forth its rivers of liquid fire; while the region around quakes as if nature shuddered at the consequences of her own energy. It is indeed no wonder that fire, among the nations of antiquity, was regarded as a thing of reverence, and that the glorious sun, as its concentration and abode, should be an object of holy worship. When untutored man first saw it spread after the thunderclap, or the rubbing of the forest branches after a storm, so as to threaten universal destruction, we cannot, in justice to his condition, reprobate the interpretation which suggested to his mind that "this tremendous power can be nothing less than the God of Nature." Men have grown familar with its energies, and have almost ceased to be moved by them. Science has made it one of our most obedient servants, whether it bursts from the cannon's mouth to produce the carnage of the battle, or is chained to the steam-engine to put forth a giant's strength in upheaving a river from the bottom of a mine, or in urging a vast ship through the winter storm. Fire, indeed, in our service, may be figured as a legion of ministering spirits, to whom no labour is difficult, and over whom we have absolute command at any moment, conjuring up one or more by the magic stroke of a flint and steel, or by well-known means which are more convenient.

Combustion, although one of the most familiar phenomena of nature, and one which must have pressed itself on the attention

of thinking men of all ages, remained a mystery until our own times; and even at this moment the main difficulty remains unexplained. Many hypotheses have, indeed, been advanced in explanation, and some of them belonging even to comparatively modern times, are now without a single advocate to support them. It is unnecessary to recall them from the oblivion into which they have deservedly sunk. To this we may, however, make one exception, in the case of the *phlogistic theory*, on account of its forgotten importance, and the impression which it made upon our old scientific literature. According to the opinion referred to, every combustible substance was supposed to contain a quantity of something denominated *phlogiston*, which, on being disengaged or set free, became obvious to the human sense, as light and heat. As an instance, the white oxide of zinc, popularly known as *flowers of zinc*, into which the metal is converted by burning, was supposed to be zinc deprived of its phlogiston. When this oxide is heated with charcoal, the metal again appears; and this was thought to be explained by saying that it receives phlogiston from the charcoal. All other cases of alteration by combustion were similarly accounted for—by the loss or acquisition of that thing called phlogiston.

The illustrious Lavoisier* had the merit of first clearly disproving this hypothesis, by simply showing that the flowers of zinc, and all oxides similarly obtained, are heavier than the piece of metal from which they are produced. Instead, therefore, of losing something by combustion, there is a positive augmentation of weight—a positive acquisition—to be accounted for. The experiments instituted by the author, to prove this fact, enabled him to show very clearly that combustion was merely the act of two substances combining chemically; but, happening all to be of a similar nature, they led him into an error almost as great as that from which he had escaped. Having proved satisfactorily that the increase of weight, arising from his cases of combustion, was exactly equal to the quantity of oxygen gas which disappeared in the process, he thence concluded that, in *every* case of combustion gas must always be one of the combining substances, and that the light and heat given out are elements which it contains in a latent state. This theory succeeded in explaining most cases of ordinary combustion—all our common fires and methods of illumination; but it was soon found to require great modifications, which will best appear from a statement of the true conditions of the question.

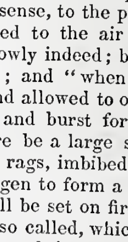
We have already seen what is the effect produced when bodies are compressed, or by any means reduced in volume—as when air, compressed in the match-syringe, lights tinder, or a lime-loaded ship, springing a leak, takes on fire by the lime uniting with the water, consolidating it, and eliminating its heat of fluidity; and we may here remark, that when the temperature of a substance exceeds 1000 degrees, the body usually becomes luminous—as when a piece of iron, or any other solid not readily dissipated by the heat, is placed in a common fire till it becomes, like the coals, red-hot. These two facts, placed in juxtaposition, form a basis for the explanation of the ordinary process of combustion or burning. Chemical affinity is the condensing power called into operation, and this is usually active and intense in proportion to the temperature under which it takes place.

In popular as well as in scientific language, a body is said to burn when there is an emission of light and heat; and, to the world at large, combustion is only of importance as an illuminating and warming process. If the body rendered luminous be solid, the effect is *fire;* but if it be gaseous, it is *flame.* Taking, therefore, the largest and most scientific meaning of fire and flame, they are simply the phenomena arising from the chemical union of two dissimilar substances going on with great intensity of action; and according to the nature of the substances combining, the appearances vary. In ordinary cases, one of the combining substances is oxygen. This may be termed the great combining substance of nature. Of all other substances it is the most widely distributed. It forms four-fifths of water, almost one half of our solid rocks, and one-fifth of our atmosphere. It is, therefore, present wherever man can be, and is ready at all times to unite with any one of that class of bodies called *combustible,* when exposed to it at the necessary temperature. In chemistry, again, most simple bodies come under the head of combustible; but the most remarkable of these are charcoal and hydrogen gas. The first of these is the basis of all our fuel, and exists in chemical union with the latter in the gaseous matters which we burn for illumination. Coal gas, for instance, is a manufactured compound of hydrogen and carbon or charcoal, and it is by the gradual conversion of tallow, oil, and wax, into the same gaseous compound that our candles and lamps continuously pour forth their light—the aëriform state is produced by the elevation of temperature which is maintained during the process, and the combustion which takes place is the effect of the combination of the hydrogen evolved, and the atmospheric oxygen in which it burns.

Of the substances called combustible—and thus called because they combine with oxygen so energetically as to become luminous—there are only a few which will begin to burn at ordinary temperatures of the atmosphere. The metallic basis of potash, called *potassium,* inflames immediately on being brought into contact with the coldest ice—so great is its affinity for oxygen, that it seizes upon it from water at all temperatures. To inflame *sodium,* the metallic basis of soda, by contact with water, a temperature of 80° is sufficient. But other bodies require higher temperatures. Phosphorus, for instance, must be heated to 120°: at that point it begins to burn, and the combustion proceeds with great splendour. Sulphur ignites at 300°, charcoal at 700°, and hydrogen at 800°. It appears that up to particular temperatures—depending on the chemical nature of the body—the attraction of the atoms among themselves is sufficient to resist their attraction for oxygen; but when the combustion once begins, the temperature, from the effect of the combustion itself, rises instantly beyond the degree necessary for the commencement of the process. Thus, oxygen and hydrogen begin to burn or combine at 800°; but the temperature of the flame is not less than 5000°.

It may be here observed, that the chemist has frequently to consider cases of the combination of the combustible with oxygen, when the phenomena evolved do not warrant the application of the term combustion, in the popular sense, to the process. A piece of phosphorus, for instance, exposed to the air at the ordinary temperature of 50° or 60° burns, slowly indeed; but still there is an evolution of both light and heat; and "when a few sticks of this substance are laid together, and allowed to oxidize, they warm each other so much as to melt and burst forth into vivid flame. The oils, and tallows, if there be a large surface exposed to the air—as when cotton or linen rags, imbibed in oil, lie in a heap—combine so rapidly with oxygen to form a sort of resin, that by the heat evolved, the mass will be set on fire; and hence the origin of those spontaneous fires, so called, which consumed the naval arsenal of St Petersburgh, and, in many cases, cotton mills in England. To this cause, also, may be ascribed the light that issues from points in the surface of a marsh or bog, and the luminous appearance which fish assume when decomposition has just commenced. The energy of this slow combustion may be much increased by heat applied below the point which produces rapid action: thus, tallow, when heated below redness, burns with a pale lambent flame, invisible in daylight, but still so marked, that if plunged into a vessel of pure oxygen gas, the whole mass bursts into brilliant combustion."

It is upon this increased energy in the process of slow combustion, produced by a slow heat below that at which a body is inflamed, that the construction of the *aphlogistic* or flameless lamp is founded. If a wine glass, or better, a wide-mouthed phial, be rinsed inside with strong alcohol or ether, and a coil of fine platinum wire, heated to redness, be suspended in the middle of the glass or phial, it will remain red till all the alcohol or ether is exhausted. The reason is this: the glass becomes filled with a mixture of air and inflammable vapour, which by the influence of the platinum is made to combine; and by this combination sufficient heat is evolved to prevent the cooling of the wire, which is thereby kept ignited so long as any of the combustible material remains. In practice, the platinum wire is fixed over the wick of a spirit lamp; and the lamp being lighted in the ordinary way, is blown out as soon as the platinum has become red-hot; and this



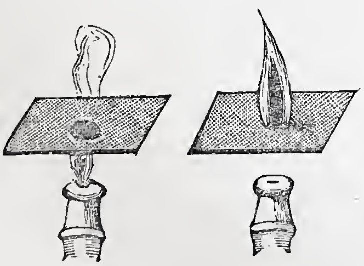
* Were we inclined to be controversial, we would here put in a claim for the famous Dr. Robert Hooke, by whom the chief positions of the Lavoisierian theory were advanced as early as 1665. Owing to circumstances, however, his opinions were forgotten; and there is much probability that they were totally unknown to Lavoisier.

continues to glow until the lamp has been emptied of its spirit —the latter ascending through the capillary wick, and forming over its top a little explosive atmosphere in which the platinum is immersed.

This property of platinum appears to depend upon a power which it possesses of attracting to its surface, in a condensed form, a layer of the particles of whatever gaseous mixture it is placed in; for if its surface be in the slightest degree soiled, it ceases to exert this action, and by increasing the surface, its energy may be augmented in a remarkable degree. If in the form, for instance, of a spongy mass, a little ball of it be immersed in a mixture of oxygen and hydrogen, (in the proportion in which they exist in water,) it causes them instantly to explode; the oxygen and hydrogen being absorbed into the pores of the ball, and brought into intimate contact with its metallic particles, unite, and thereby evolve so much heat as to raise the temperature of the ball sufficiently high to inflame the remaining gas.*

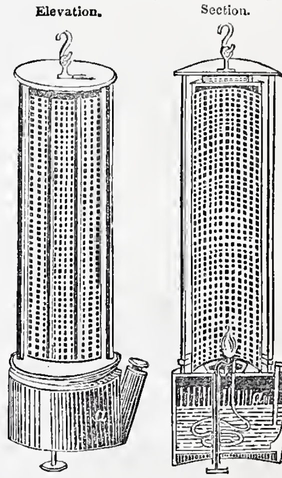
The circumstance that substances require a certain preparatory temperature before they begin to combine with oxygen, is one of those important provisions in nature which excites our admiration. All our ordinary combustibles may be exposed at common temperatures to the contact of atmospheric air. There is little danger of a piece of coal, for example, catching fire; but had its cohesive attraction been very small, and its affinity for oxygen greatly in excess, we could not then have had the benefit of it to maintain our fires—for as really happens to phosphoretted hydrogen gas—a gas which differs from that with which our streets and houses are lighted, in having phosphorus instead of carbon—it would inflame on the first exposure to the atmosphere, and burn with an incessant and alarming intensity. On the other hand, were the affinity for oxygen greatly less, and the cohesive attraction more powerful, the difficulty of commencing and maintaining our fires would be at least much increased. The Welsh stone coal affords some approximate notion of the effect of slight increase of the force of aggregation with little more than a perceptible difference of chemical constitution. That material can only be made to burn in large masses, or when mixed with more inflammable coal or other fuel, or is fed by air already heated. When a fire is small and does not give out enough of heat to supply the absorption going on among the bodies around, and maintain the inflammable temperature of the substance, the combustion is speedily extinguished. Thus, if a common coal fire be neglected, and the remains of the fuel are not gathered together occasionally, to reduce the surface of wasteful radiation, it decays, and finally is extinguished, long, perhaps, before the fuel is expended. In this way, often, much coal is burned in our common fires at temperatures so low as to be nearly useless.

The effect of the rapid absorption of heat is best seen in the case of a weak flame. A lamp with a very small wick, as a single thread, will be extinguished by bringing a cold metallic nob near it, or letting down a metallic ring over it; but if the nob or ring be hot, the effect will be reversed. By a more powerful refrigerating process, even a candle, giving a considerable flame, may be extinguished. The effect of solid bodies, and the great rapidity with which they conduct the heat which they receive, is very beautifully illustrated by bringing a piece of wire gauze over a jet of ignited coal gas: the flame is at once arrested at the lower surface of the gauze, and although the gas and air pass through with perfect freedom, and form as they pass an explosive mixture, yet no inflammation is propagated. Again, if the gas be allowed to pass through the gauze, and then be ignited at its upper surface, it will burn there; but although the



space between the jet and the gauze be occupied by inflammable material, the flame cannot pass down. The explanation is, that the metallic tissue conducts away the heat so rapidly, that the temperature does not attain the requisite degree of elevation to begin the combustion. It is this principle which Sir H. Davy has applied so successfully to the construction of a safety-lamp for mines, and "which constitutes one of the most beautiful instances of the advantage which may practically flow from what, superficially considered, might appear a mere abstract principle in science. The fire-damp, or light carburetted hydrogen, which, issuing from the minute fissures in the excavations of a coal mine, is diffused through the air introduced for the purpose of ventilation, often forms an explosive mixture, which being set on fire by accident or negligence, detonates with awful violence, and destroys all living beings which may at the time be in the mine. This gas is one of the least inflammable, and hence, most fortunately for humanity, one to which the principle of cooling orifices may be most successfully applied." The lamp is depicted on the margin in section. It consists essentially of the part *a*, in which are contained the oil and wick for supplying light; and this part—the lamp properly so called—is surrounded by a cylinder of wire-gauze of about 1500 orifices in the square inch. Within this the inflammable mixture may explode; but the flame cannot pass out, so, therefore, the combustion is prevented from communicating to the external mass of air; and "thus the miner, guided by the never-failing indications of his lamp, passes along through galleries under ground, where the emission of a spark would cause destruction; he measures by the appearance of the (flame of the) lamp, the actual condition of the air he breathes, and its fitness for respiration. If the air be pure, the lamp burns clear as in the upper air; if some fire-damp be present, the lamp shows much less light, the flame becomes red and smoky; if the noxious impregnation be still increased, the flame of the lamp itself becomes extinguished, and the cylinder of metallic gauze is filled with a sheet of lurid flame; the miner being then enveloped by an atmosphere fully explosive, and even fatal to life if it be long respired. If he proceed still farther, all flame is lost; for as the fire-damp then predominates, there is produced, from a deficiency of oxygen, only a slow invisible combustion; but even this is made, by the sublime genius of the inventor, to give the miner the last warning to return to safer regions; a sheet of thin platinum being coiled up and hung over the wick of the lamp, becomes ignited as in the aphlogistic lamp, and continues to emit a faint but most useful beacon-glow, until an atmosphere is obtained where there is oxygen enough to support a rapid combustion, or until a place is reached, so destitute of oxygen, that no combustion whatever can take place."—*Kane.*

Elevation. Section.



Combustion takes place only at the point where the two substances which enter into combination are in contact. This is well seen in the flame of an ordinary gas jet: the true combustion is limited to a thin exterior sheet. All within this is totally dark and occupied by the combustible material in the state of gas. This is readily seen by holding a piece of fine wire-gauze over the flame, and looking down upon it: the exterior sheet appears as a luminous ring, while the interior is dark. That this dark interior is composed of inflammable gas may be proved by igniting it upon the other side as it passes through the gauze. On a still closer examination of the flame, it is found to be surrounded on all sides with an exceedingly thin film of blue flame. The eye does not readily perceive this universal blue-margin, being dazzled by the white light; but if a piece of thick card, of precisely the same size and shape as the white part of the flame,

* See Dr. Kane on Combustion.—This most remarkable property of spongy platinum is taken advantage of for the purpose of procuring instantaneous light by means of the hydrogen gas lamp, which we shall take an opportunity of describing when we come to treat of hydrogen as a chemical element.

be interposed between it and one eye—the other being shut—it will appear surrounded by this blue marginal flame. Another very distinct part is the base of the flame—every one is aware that this is blue and illuminous, and the fact has given rise to much speculation as to its cause. All the phenomena, however, admit of easy explanation. The interior part of the flame remains black, and is occupied by gas incapable of burning, from want of access to the external air; and the external white part by which it is enveloped is the result of true combustion at the surface of contact of the gas with the combining oxygen. The blue film surrounding the white body of the flame, and the blue appearance assumed by the lower portion, belong, as effects, to the same cause—an inferior temperature. This has been very decisively proved by Professor Donovan, by some very simple and easily repeated experiments. To try the effects of lowering the temperature of the flame of a jet of coal gas, he prepared a hollow cylinder of ice, and enclosed the jet in it as in a lantern. The flame instantly became blue, showed almost no light, and at length went out. A similar effect, as before observed, is produced—it may be less perfectly—by bringing any cold body nearly in contact with the flame: in all cases blueness is increased in proportion to the refrigerating power. The solution is therefore plain: the cold atmosphere cools down the whole margin of the flame, and causes the blue film already noticed; and the bottom of the flame owes its more remarkable blueness to the proximity to the metallic burner which conducts away the heat, and more so still to the constant current of cold gas perpetually ascending to supply the flame. To prove that the blue part is not so hot as the white portion, it is only necessary to roll up a bit of paper like a match, and run it upward through the axis of an argand burner from the underneath crutch, so that the top of the paper may stand in the axis of the hollow cylinder of blue flame; it will there remain unaltered; but if the paper be pushed up toward where the flame begins to whiten, it will instantly take fire. The best circumstances for the experiment are, that the flame, included in a glass chimney, shall be short and cylindrical throughout, and not coalescing at the top, and the paper should be viewed by looking down through the axis of the flame. A still more simple proof that the current of cold gas from the holes of the burner, cools the flame, and renders it less luminous consists, in heating a wire to redness in the flame, and then passing it into the current near the burner: its brightness is instantly obscured by cooling.

"If the cooling of the flame," says Mr Donovan, "were really the cause of its blueness and deficiency of light, I thought, that by removing the cause of its cooling, the blue might be changed into white, like the rest of the flame. I therefore tied a bladder filled with coal gas to a long tobacco pipe, the bowl being removed. On pressing the bladder, and inflaming the gas, it gave off a long stream of flame, of which more than an inch was blue, and the rest white. About three inches of the end of the pipe were now heated to whiteness, and maintained at this degree; the bladder being pressed, the flame burnt white throughout, except about one eighth of an inch, which was somewhat bluish. For this experiment a red heat will not answer. A non-explosive mixture of common air and coal gas, passed through an argand burner, afforded a blue flame without any white light; for the dilution of the inflammable gas by an incombustible one prevented the flame from reaching the temperature necessary to its becoming fully luminous. I caused a massive argand burner, three inches in diameter, with thirty capillary holes, to be made; and having passed good coal gas through it, and kindled the gas, I found that the flame was almost totally blue, and showed scarcely any light: the great quantity of brass, and the cold current, were adequate to deprive the capillary jets of flame of the quantity of heat required for the production of white light. If a red-hot iron be introduced into the blue part of a gas flame, the latter instantly becomes white; but if the iron be cold, it has no effect. The flame of a taper, held very close to the blue flame, renders it whitish; but the flame of burning sulphur applied, has not this effect, as it is not sufficiently hot for the purpose. Although the blue part of the flame is colder than the white, a thread of glass grows apparently of a brighter red heat when held in the former; because the whiteness, brilliancy, and semi-opacity of the white flame, conceal the heat to which the glass is raised in it: but this is not the case in the blue flame; for it, being but little luminous, and very transparent, affords a contrast with the redness of the glass."

The knowledge that the blueness of the base of a gas flame is caused by inferior temperature, induced in the way explained, has of late led to a very beneficial and simple improvement in the mode of constructing the branches of gasaliers. It consists in bending the termination of the pipe in such a way that it passes directly over the axis of the jet, at such a height above it, that the top of the flame, when the gas is lighted, plays constantly upon the pipe, which is thereby heated; and as all the gas consumed must pass through this heated portion, it issues out at a considerably elevated temperature. The effect is, that a less depression of the temperature of the base of the flame is produced; very little blueness is perceptible, and, consequently, more light is obtained from the same amount of gas.

In the flame of a candle there is scarcely any blue light, because the carbonized wick is the worst of all conductors of heat, and therefore cools the flame very little. A long wick, however, cools the flame by radiation, and there is a diminution of light, although the flame does not become blue. The supply of combustible matter is derived thus: the tallow or wax of which the candle is composed, is first liquefied, and then drawn up through the interstices of the wick by capillary attraction. As it comes into contact with the source of heat, it is boiled and converted into vapour; this vapour ascends in a column by reason of its lightness, and quickly, though progressively, rises to the temperature which enables it to combine with the oxygen of the surrounding air. The remaining part of the explanation is general: the combination which takes place copiously develops heat, and produces the white bright light of the flame. But this combination can only take place at the exterior surface which is in contact with air, and the flame therefore, as far as light and heat are concerned, is hollow. But as the gas in the interior of the flame ascends, it progressively gets into contact with a fresh portion of the atmosphere, whence, deriving oxygen, it enters into combination, and increases the combustion at a more and more elevated position. Thus the flame gradually tapers to a point, at which the temperature falls below that necessary for combustion, and the flame terminates, although in many instances large quantities of combustible matter pass off unconsumed. This is readily proved by bringing a ring of iron intensely heated over the apex of the flame of a lamp or candle, when it will be observed that the flame ascends considerably higher than it previously did, and gives out an additional quantity of light. It is indeed the waste of the combustible matter which constitutes the smoking of a candle or lamp; and this always takes place when the heat produced by the flame is diminished, as in an untopped candle, and where the supply of the oxygen is insufficient for the total combustion of the gaseous combustible. It was to remedy this defect in large flames, that the argand burner was introduced: in this, air is admitted to the inside of the flame, and the combustion is in general much more complete. The tall glass chimneys employed have also their use in quickening the currents of air, and thereby hastening the combustion.

The temperature of flame is in all cases very high, even when it is but little luminous; but it is not to be supposed that all flames of equal temperature give out equal quantities of light. Temperature of flame is not the only cause of light. Thus the flame which pure hydrogen gas gives is pale and blue; but a wire held in it becomes highly luminous; and the flame of mixed oxygen and hydrogen escaping in a very narrow jet, may itself be scarcely visible; but a bit of lime placed in it acquires a brilliancy which the eye cannot look upon. The flame is in fact the most intense which human art can excite. The most refractory metals melt before it like wax in a common taper. It is the flame in fact of the oxy-hydrogen blow-pipe, and with a lime-ball it constitutes the famous Drummond light. It is, moreover, to be remarked, that this intense flame gives out no perceptible quantity of heat by radiation, until some solid body is introduced into it.

These, and other facts, have led to the conclusion, that the light given out by flame is in proportion to the quantity of solid matter in it. Hydrogen gives scarcely any light, because it is a gas, and requires a temperature far above that required by any solid body to render it even visible. Sulphur, in burning, emits little light for a similar reason; and even phosphorus, when it burns under circumstances to form only a volatile body, gives but a feeble light: but when the result of its combustion is a fixed product, (phosphoric acid,) it affords one of the most brilliant instances of combustion. Iron and zinc burn brilliantly, because during com-

bustion they form solid compounds with the combining oxygen. It is, moreover, upon the same principle, that the superior light elicited in our methods of illumination, is explained. Our common coal gas, which we have already characterized as hydrogen, holding a quantity of carbon in solution, as much surpasses pure hydrogen in its lighting power, as it falls short of it in its power of heating. The oxygen of the air, during the combustion, first seizes upon a certain portion of the hydrogen of the gas, and separates from it the particles of the carhon ; these particles are precipitated in the flame, and hecome so many solid bodies, most intensely heated and luminous. It is in fact these particles which constitute smoke, and it is in reality this smoke which is the great source of light : candles which eould not form smoke, would give out little light in burning. All the carbon separated does not however pass off as smoke, unless the temperature of the flame he very low ; it in its turn enters into eomhination also with the oxygen of the air, forming carbonic acid (choke damp), while the product of the oxygen and hydrogen is water. That this decomposition of gas really occurs is readily proved hy placing a piece of wire gauze over the flame ; at the apex no carbon (soot) is deposited, hut in passing the gauze downward, the flame hecomes dull, and the carhon which should have rendered it luminous, is in part deposited upon the gauze, and partly passes through its meshes, and may as already observed, he ignited ahove. Immediately over the orifice of the jet also, no carhon is obtained, the temperature at that point being too low to decompose the gas.

The determination of the quantity of heat, produced during the combustion of a given quantity of combustible substance, is a prohlem not only of great scientific interest, but of great importance in the useful arts and manufactures, as upon it depends the economic value of all sorts of fuel. There is, however, no subject in experimental physics in which more remains to he discovered, and in which the process of discovery seems attended with more difficulties. Lavoisier and Laplace, Drs Dalton and Crawford, Count Rumford and Watt, all took up the suhject ; but the results at which they severally arrived are so discordant, that no relianee can be placed upon them. The late researches of Despretz and Bull, which appear to have heen conducted with more attention to accuracy than any former ones, have led, however, to a very interesting rule which may serve as a basis for succeeding experiments ; it is, that in all cases of comhustion, the quantity of heat evolved is proportional to the quantity of oxygen which enters into combination. Thus Despretz found that 1 lh. of oxygen, uniting with the following comhustihles, raised the quantities of water given from the freezing to the boiling point ; namely with

| | | | |
|---|---|---|---|
| Hydrogen it heated | 29½ lbs. | Alcohol it heated | 28 lbs. |
| Charcoal, . | 29 | Ether, . | 28½ |

The mean of these results gives 28¾ lhs. as the quantity of water which the eombination of 1 lb. of oxygen in eombustion can elevate 180°.

This is however liahle to some very curious changes ; for the same quantity of oxygen was found hy the experimenters when comhining with iron, zinc, and tin, to give out almost exactly twice as much heat as that indicated in the table ; and, further, when phosphorus burns slowly, so as to form phosphorous acid, it heats in combining with a pound of oxygen 28 lhs. of water ; hut when it hurns hrilliantly, forming phosphoric acid, the heat evolved is doubled, or is the same as that produced with iron, zinc, and tin. Dr Kane remarks on this, that in cases where the smaller proportion of heat is evolved, the products of the comhustion are all volatile ; and where the larger proportion is produced, the products are fixed and solid ; even in the case of phosphorus, when it combines producing least heat, it forms a volatile product, hut one which resists a full red heat, in the case where the combination has heen complete.*

Supposing this rule of Despretz and Bull to he correct, the following table, which we give on the authority of Dr Ure, may be reckoned valuable as a hasis for more extensive experiments. It shows in the fourth column, the weight of atmospheric air, whose oxygen is required for the complete comhustion of a pound of each of the combustibles named in the first column ; and this, together with the other two columns, may be authentically compared with the foregoing rule.

| Species of Combustible | Pounds of water which a pound can heat from 08 to 2128. | Pounds of boiling water evaporated by 1 pound. | Weight of atmospheric air at 328. to burn 1 pound. |
|---|---|---|---|
| Perfectly dry wood . | 35·00 | 6·36 | 5·96 |
| Wood in its ordinary state | 26·00 | 4·72 | 4·47 |
| Wood eharcoal . . | 73·00 | 13·27 | 11·46 |
| Pitcoal . . . . | 60·00 | 10·90 | 9·26 |
| Coke . . . . | 65·00 | 11·81 | 11·46 |
| Turf . . . . | 30·00 | 5·45 | 4·60 |
| Turf charcoal . . | 64·00 | 11·63 | 9·86 |
| Carburetted hydrogen gas | 76·00 | 13·81 | 14·58 |
| Oil, Wax, Tallow . . . | 78·00 | 14·18 | 15·00 |
| Alcohol of the shops . | 52·60 | 9·56 | 11·60 |

"The quantity of air stated in the fourth column is the smallest possihle required to hurn the combustible, and is greatly less than would he necessary in practice, where much of the air never comes into contact with the hurning hody, and where it consequently never has its whole oxygen consumed. The heating power stated in the second column is also the maximum effect, and can seldom he realized with ordinary hoilers. The draught of air usually carries off at least ¼ of the heat, and more if its temperature he very high when it leaves the vessel. In this case it may amount to one half of the whole heat or more ; without reckoning the loss by radiation and conduction, which, however, may be rendered very small by enclosing the fire and flues within proper non-conducting and non-radiating materials."

It may perhaps he hastily concluded, from this review of the subject, that comhustion viewed as a physical prohlem, admits of no difficulty ; that the heat evolved is that previously latent in the combining oxygen, and that the light is a consequence of the heat. This is the Lavoisierian theory already referred to ; and for all the common cases of comhustion it offers a complete solution. But the progress of modern chemistry has hrought under notice very many cases in which it as completely fails. Thus when gunpowder is heated, it explodes with the production of light and heat ; but these cannot result from latent heat ; for the products are mainly gaseous, and the capacity of the whole for heat being increased, we should expect the production of an intense degree of cold When charcoal is hurned, much heat also is evolved, hut so far from a gas in this case hecoming a solid, a solid is changed into a gas (carbonic acid), and should therefore produce an equivalent degree of cold. Lavoisier, in this case, appealed to the relative specific heats of the gases before and after union, and if he could have shown that the carhonic acid formed, had a greatly inferior specific heat to oxygen, then the evolution of a quantity of heat might be accounted for in the same way as occurs with water and sulphuric acid ; hut the contrary is true ; the carbonic acid has a greater specific heat, hulk for hulk, than the oxygen from which it is formed in the proportion of 1258 to 977. We shall hereafter meet with many cases equally inexplicahle upon the supposition that the heat evolved is latent in the comhining oxygen, hesides numerous instances in which oxygen has nothing whatever to do in the process. As one instance, there is an oily-looking liquid composed of the two gases, chlorine and nitrogen : when heated to 200° it explodes with tremendous violence, and the evolution of considerable light and heat ; its constituents are simply set free, and forthwith expand to six hundred times the volume of the compound.

Whence then results the heat evolved during comhustion ? However humiliating it may be, we are obliged to confess that the question does not as yet admit of any *general* answer. All that we can pronounce upon is, that chemical combination is a source of light and heat. It is however impossible to arrest inquiry at this point, and accordingly we find the phenomena attempted to he explained at one time in conformity with Dulong's law of specific heats (page 164), upon the hypothesis, that a numher of atoms cohering, the specific heat of some of them is expelled, thus producing the rise of temperature ; at another we are directed to seek the cause in the disengagement of elec-

* The non-chemical reader may be informed that both the phosphorus and phosphoric acids, are combinations of phosphorus with oxygen ; but the latter contains double the quantity of oxygen which the former contains.

tricity which accompanies all manifestations of chemical action. The first of these positions, although possessed of considerable theoretical interest, we may at once pronounce utterly inadequate as a physical explanation; the second will require examination when we are in a better condition to understand the evidence in its favour, and the difficulties with which it is beset. In the mean time, however, it will be most prudent to refer the heat of combustion to the general stock which all matter contains, without pronouncing upon any mode bv which such heat is restricted in its recondite development.

The living animal body presents to us another source of heat, perhaps analogous in its development to that of combustion, and assuredly as little understood. The investigation of this interesting and difficult subject belongs properly to physiology; but we may nevertheless remark here, that there is provided in the animal system some unknown means, by which the living body maintains during health the same degree of heat in all vicissitudes of climate and weather. It is rarely of the same temperature as the surrounding air; the animals of the polar regions are much warmer than the ice on which they dwell, while those of the equatorial regions are colder than the air which they breathe. Birds have not the temperature of the atmosphere in which they fly, nor fishes of the water in which they live. The last, however, approach very closely to this condition; and when we descend to the reptile class, we find the temperatures of the medium and of the animal nearly coinciding. The following table places the subject in a clearer light than any amount of discussion; it is the result of numerous experiments, most of which are by Dr. John Davy.

MAMMIFEROUS ANIMALS.

| | Atmospheric temp. | Animal temp. |
|---|---|---|
| Man, | ?° | 98° |
| Monkey, | 86 | 102 |
| Hare, | 80 | 100 |
| Tiger, | 80 | 100 |
| Dog, | 80 | 102 |
| Cat, | 77 | 102 |
| Horse, | 79 | 101 |
| Ox, | 79 | 102 |
| **BIRDS.** | | |
| Kite, | 80° | 100° |
| Sparrow, | 80 | 108 |
| Pigeon, | 78 | $109\frac{1}{2}$ |
| Hen, | 78 | 110 |
| Goose, | 78 | 106 |
| Drake, | 78 | 110 |
| Crow, | 67 | 104 |

AMPHIBIOUS ANIMALS.

| | Medium temp. | Animal temp. |
|---|---|---|
| Frog, | 76° | 77° |
| Testudo-Mydas, | $89\frac{1}{2}$ | 85 |
| Serpent, (green) | $81\frac{1}{2}$ | $88\frac{1}{2}$ |
| Do. (brown) | $82\frac{1}{2}$ | $84\frac{1}{2}$ |
| Adder, (brown) | $82\frac{1}{2}$ | 90 |
| **FISH AND MOLLUSCA.** | | |
| Shark, | 74° | 77° |
| Trout, | $55\frac{1}{2}$ | $57\frac{1}{2}$ |
| Flying-fish, | $77\frac{1}{2}$ | $77\frac{3}{4}$ |
| Oyster, | 81 | 81 |
| Lobster, | $79\frac{1}{4}$ | 79 |
| Crab, | 72 | 72 |
| **INSECTS.** | | |
| Beetle, | 76° | 77° |
| Glowworm, | 72 | $73\frac{1}{2}$ |
| Wasp, | $74\frac{1}{2}$ | 76 |

We have placed man at the head of the table. The temperature which he maintains, is the same while breathing the atmosphere of a polar winter, sufficiently low to freeze mercury, and when scorched by a tropical sun, where the thermometer stands at 110° in the shade. The temperature is, moreover the same in all cases, whether they are nourished exclusively with butcher-meat, as is the case with the vaida of India; whether they eat only vegetables like the priests of Buddha; or whether they be Europeans, consuming all sorts of aliments. In the animal economy, there must therefore exist certain properties by which the temperature is regulated, its excess checked, and its defects supplied. The provisions made for the first of these conditions are not difficult to comprehend. The process of perspiration and evaporation, radiation from the surface of the body, and the loss of heat by contact with the surrounding air, are perhaps sufficient to explain why the heat generated in the system, does not accumulate so as to raise the temperature indefinitely. "When the temperature of the climate is low, radiation and conduction, and the loss of heat by contact of cold bodies, operate powerfully in proportion to the difference between the temperature of the surrounding objects and that of the body. In warm weather, and in hot climates, where the difference between the temperature of the body and that of the air and every surrounding object is small, these effects are perpetually diminished; but then the heat carried off by perspiration and evaporation from the skin is proportionally increased, so that, as the activity of one principle is abated, the other receives increased energy, and the temperature of the body is regulated and fixed."

But what are the means provided in the animal economy to maintain this temperature at its maximum limit? The striking analogy which respiration bears to ordinary combustion—in both of which oxygen gas combines with carbon and forms carbonic acid—furnishes the foundation of the earliest attempts to resolve the problem. The theory is this: oxygen being taken into the lungs by inspiration, combines with the carbon of the venous blood, thereby decarbonizing it, and converting it into arterial blood, and also it was at first supposed, with a certain amount of hydrogen; and during the combination, a quantity of heat is evolved as it is in combustion, proportionate to the quantity of oxygen which disappears, and this heat is circulated by the blood to all parts of the body. It was soon perceived, however, that under these circumstances, the lungs ought not only to be the hottest part of the body, but that the heat evolved would be capable of injuring these organs. To remove this difficulty, Dr Crawford instituted experiments to prove that the capacity of arterial blood for heat exceeds that of venous in the ratio of 1030 to 892. From this he inferred, that the dark blood within the veins, at the moment of being arterialized, acquires an increase of latent heat, and that while circulating through the body, and gradually assuming the venous character, it suffers a diminution of capacity, and dismisses an amount of heat proportional to this diminution. This explanation meets the objection, but unfortunately for the hypothesis, beautiful as it unquestionably is, the leading *fact* on which it is founded has been disputed. Dr John Davy instituted a series of experiments, with a view to test the accuracy of those made by Dr Crawford, and arrived at the conclusion, that there is no perceptible difference between the specific heats of arterial and venous blood; and therefore the heat evolved in respiration cannot be consumed by any increased capacity which the blood acquires in the lungs. Another theory was proposed by Lagrange. According to him, the oxygen of the air inspired is dissolved by the blood in the lungs, and carried with it through the system. In its progress it is gradually combined with carbon and hydrogen, performing thus a kind of incipient combustion, and on returning to the lungs, it is expired in the form of carbonic acid and watery vapour. In this way, the question concerning the capacity of the blood for heat may be entirely disregarded.

Some physiologists deny the agency of respiration altogether, in maintaining the animal temperature, and ascribe the evolution of heat in the system, to the influence of the nerves. The chief foundation for this opinion, is in some experiments by Sir Benjamin Brodie, upon rabbits recently killed by narcotic poisons, or division of the spinal marrow. In these experiments it was found, that by inflating the lungs, the blood continued to circulate, oxygen gas disappeared, carbonic acid was evolved, and the usual changes of the colour of the blood took place with regularity; but notwithstanding the concurrence of all these circumstances, the temperature fell with equal if not greater rapidity, than in another animal killed at the same time, but in which no artificial respiration was performed.

Other physiologists, in repeating the experiments of Brodie, have however arrived at an opposite conclusion as to the effect of artificial respiration—they have found it to retard the process of cooling very sensibly. There are indeed many circumstances, which, taken together, form a body of evidence almost irresistible, that the source of animal heat is in some way or other dependent upon, or connected with, the process of respiration. Thus, it is found that in all animals whose respiratory organs are small and imperfect, and which, therefore, consume but a comparatively minute quantity of oxygen, and generate little carbonic acid, the temperature of the blood is low, and varies with that of the medium in which they live. In warm-blooded animals, on the contrary, in which the respiratory organs are large, the temperature is uniformly maintained; and those have the highest temperature, whose breathing apparatus, in proportion to the size of their bodies, is largest, and which consume the greatest quantity of oxygen, and evolve the greatest amount of carbonic acid. In the same animal also, the state of the circulation has an obvious connexion with the power of generating heat. When the blood circulates sluggishly, the temperature is low, the oxygen consumed comparatively small; but on the contrary, when the circulation is quick, much oxygen is consumed, and carbonic acid is produced largely, and heat is generated with rapidity, and is abundant. It has further been observed, that when an animal is placed in a very warm atmosphere, so as to require little heat to be generated within its own body, the consumption of oxygen is usually small, and the blood within the veins retains the arterial character. There are likewise some young animals, such as puppies and kittens, which require so small a quantity of oxygen to support them, that they may be de-

prived of that gas altogether, for upwards of twenty minutes, without material injury; and it is remarkable, that so long as they possess this property, the temperature of their bodies sinks rapidly, by free exposure to the air. As they grow older, they become more and more able to maintain their own temperature; and, at the same time, their power to endure privation of oxygen ceases. The same observation applies to young sparrows, and all other birds which are naked when hatched; while young partridges, which are both fledged and able to retain their own temperature at the period of quitting the shell, die when deprived of oxygen, as rapidly as an adult bird.

But while we are inclined to believe, that the conversion of oxygen into carbonic acid in the lungs, during the process of arterialization, is a source of heat, we are not prepared to admit that the whole animal temperature is maintained by that process. The converse indeed has been very clearly proved, by the researches both of Dulong and Despretz. Thus, it is very satisfactorily shown, that the loss of heat by the human body, under ordinary circumstances, during 24 hours, from all appreciable causes, is equal in amount to the quantity required to raise 63 lbs. of water from the freezing to the boiling point; but during that time, the quantity of carbon thrown off by the system, both by the lungs and by perspiration, would not afford more heat by combustion, than would be required to heat 36½ lbs. of water through the same range of temperature. There remains therefore of the quantity of heat generated in the body during that time to be accounted for, as much as is required to raise 26½ lbs. of water, from 32° to 212°. The origin of this remainder must be found in the action of the muscles, and in the nervous power. The influence of the last over animal heat is indeed not doubtful, and physiologists are only not agreed as to the mode in which it operates. "Its action may either be direct or indirect; that is, the nerves may possess some specific power of generating heat; or they may excite certain operations by which the same effect is occasioned. It is far from improbable, that the nerves act more by the latter than the former mode; that the infinite number of chemical phenomena, going on in the minute arterial branches during the processes of secretion and nutrition,—processes which are entirely dependent on the nervous system, are attended with disengagements of heat." This view has at least been ably defended by Dr Williams, and has now many adherents among the physiologists of the present time.

In enumerating the active sources of heat, we cannot with propriety pass over unnoticed, the great natural supply which comes to us associated with the sun's light. Without this supply—supposing that we could imagine man for a moment to exist upon the globe under its privation—vain would be all his puny efforts to remedy the defect, by artificial sources of this life-preserving agent. "The conflagration of every combustible upon the face of the earth would be insufficient to compensate, for twenty-four hours, the absence of the glorious orb of day."

It is unnecessary to refer to experiments with the burning-glass in evidence of the heating power of the sun-beams, which radiate through our system. The proof is ever present with us, and cannot be denied in whatever region of the world we take up our abode—whether suffering by excess under the vertical rays that fall upon the Indies, or benumbed with cold under the partial privation which afflicts the high latitudes of the north and south. Even without stirring from our own homes, the change of temperature from day to night, the change of the seasons, and in fact all the meteorological phenomena of nature point to the sun as the great source of heat, as well as of light, to our world. And indeed, when we extend our observation to the great masses of the universe, including the earth itself, we are irresistibly hurried on, by an accumulating code of analogies, to the conviction, that the same physical properties which observation and experience disclose to us in the limited masses with which we are immediately concerned, are those which prevail throughout all creation. Influenced in the same way, we cannot help concluding, that to those infinite systems which fill the immensity of space, heat is distributed by radiation from centres according to the same law that regulates its distribution among the bodies which surround us.

This is a subject, however, upon which we cannot at present enter; nor are we yet fully prepared to examine the hypotheses which have been put forth respecting the sun as a source of heat to the planetary system to which our world belongs. These, indeed, may be shortly stated: one assumes that the sun is an intensely heated mass which radiates its heat and light around, like a mass of intensely heated iron; the other holds that heat is merely an affection of an ethereal fluid which occupies all space, and endeavours to show that the sun may produce the phenomena of light and heat without waste of its temperature or substance, just as a bell may produce sound when it is struck, by affection of the air which surrounds it. This latter hypothesis admits of the probability that the mass of the sun may be habitable even by such forms of organic existences as live upon this earth, whereas those holding the materiality of the solar radiation are awakened to the dread contemplation of a universe carrying in itself the seeds of its own decay. The discussion, of course, involves the whole question—what is heat? and can only be entered upon with advantage when the whole amount of research both upon light and heat is before us.

Admitting that the sun's rays are the principal source of heat on the surface of our globe, we can see why temperatures vary in relation to the amount of those rays, and the position of the sun in the heavens by which they strike upon the surface with different inclinations, and therefore with continually decreasing effect from the equator to the poles.* The heating effect of the solar rays varies also with the different thicknesses of atmosphere which they traverse, owing to absorption to a variable amount. This is, indeed, no inconsiderable fraction, amounting as it does, according to the mean of the best modern experiments, to no less than twenty-eight per cent. of the whole solar radiation, even when it reaches us vertically, and through a clear atmosphere. The quantity stopped is not however totally lost: it is employed in elevating the atmospheric temperature, and possibly the greater portion of it ultimately reaches the surface. Again, the effect of the sunbeams upon the surface varies with the colour, texture, and capacity for heat and other circumstances, which are known to affect the absorbent and reflective powers of bodies—the amount absorbed and retained is not uniform. Snow and ice, which cover so large a portion of the polar surfaces, absorb but little of the sun's heat; sandy and rocky tracts also return a great proportion of it into the atmosphere; and grassy plains and cultivated fields freely absorb it by day, and as freely radiate it by night. These circumstances may be little sensible in registers of temperature; but they very seriously affect the growth of plants, and the conditions of animal life, and constitute a very important character of local climate. Elevation above the level of the sea is likewise an important element affecting local climate. In the higher regions, amidst the complications of aerial currents, which rather alternate than mingle, we find the temperature to decrease as the density of the atmosphere diminishes, in the ratio, according to Professor Forbes, of 1° F. for every 323 feet of altitude. The climate of the ocean is, moreover, very different from that of the land: it is less extreme in its variations with season, and limited within narrow ranges over the whole watery surface. The ocean is indeed a great reservoir of heat, which by its fluctuations, by the movement of tidal and oceanic currents, it is perpetually diffusing and giving out to mitigate the climates of the remotest regions. On the land, a similar, but less regular and continuous influence is exerted by the winds, which by appointed laws change and fluctuate in their paths,—causing, however, *alternation* of local temperature rather than *gradation*.

The earth may then be regarded as an absorbing and radiating body, propagating the warmth of summer, and winter's cold, both upward and downward, with a diminishing intensity, according to known laws, which explain the absence of superficial accumulation of heat derived from the sun. But although the heat received from the sun is again dissipated into the atmosphere and ethereal spaces, and although the climates on the earth appear to be constant, excepting where local circumstances of a transient nature interfere with them, it is yet found that this globe of ours contains within itself a source of heat, which in those periods of its history which it is the business of geology to unfold, must have retained its mineral constituents in a state of igneous liquefaction. This is not a matter of speculation. Observation informs us, that nothing is more variable than the surface temperature of the ground; but, as we penetrate beneath, the fluctuations disappear, and all traces of the influence of the seasons are obliterated. This depth is moderate; it nowhere exceeds a hundred feet, and rarely falls short of sixty, and seems to be con-

* Nearly in simple proportion to the cosines of latitude, and not as Mayer has it, according to the square of the cosine.

nected with the character of the soil, its conducting power, and other relations to heat. Beyond this depth, the temperature is found uniformly to rise; and although subject to irregularities, consequent on the different conducting power of the rocks passed through, the augmentation is about 1° of Fahrenheit's scale for every fifteen yards. This is about 116° for each mile. "At a depth of two miles, therefore, water could not exist as a liquid, unless from the great pressure to which it should be subjected; at four miles depth, tin and bismuth should naturally be liquid; and at five miles, lead. At a depth of thirty miles, the temperature should be so high as to melt iron; and, still more easily, almost without exception, the rocks which constitute the solid earth which we inhabit. The central heat, therefore, although insensible at the surface, is still, there is every reason to believe, in violent activity at a small depth below. We live upon a pellicle of solid crys alline rocks, with which the melted mass has been skinned over, and which extends but to the $\frac{1}{110}$ of the distance of the centre. We can therefore well imagine, that in many places, where orifices or cracks in the solid crust might form, violent manifestations of the internal fire should be produced, and the magnificent phenomena of volcanoes and earthquakes should thus arise."

This internal heat has long since ceased to affect the surface of the earth. The beautiful researches of Fourier very plainly demonstrate, that although the crust of the globe were of cast-iron, heat would require myriads of years to be transmitted to the surface from a depth of 150 miles. But the materials which actually compose the solid shell on which we dwell, are greatly inferior in conducting power. It is true that persons have been startled at the very idea of the interior of the earth being hot; and others have declaimed against it as a monstrous and insufferable doctrine. But facts are stubborn, and accumulated thousands of these bear evidence, that the deeper we descend, the higher is the temperature we experience, and that too in situations far remote from volcanic action, and in rocks of every chemical character. It is therefore not without reason, that geology represents the earth as a cooling globe, very hot within, and still cooling slowly; so slowly indeed, that the effects of the contraction due to the refrigeration may not be perceived by astronomers to alter the length of the day for thousands of years to come.

There is yet another important source of heat to be considered, namely, electricity; but the discussion of this interesting subject must be referred to its proper place. We have also to consider, on the subject of heat, the phenomena of diathermancy and polarization; but these will be most conveniently illustrated in connection with the analogous phenomena of light. To this subject we next turn our attention.

# MATHEMATICS.

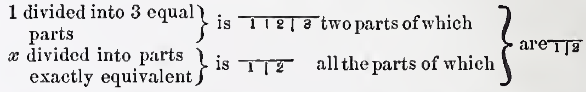
## CHAPTER VI.

### COMMON FRACTIONS.

1. As formerly observed, when we are required to speak of length, we choose some precise portion—any we please, and determine the relation which this portion bears to the quantity whose measure we desire to express. It may frequently happen, however, that the unit agreed upon, and which we call *one*, and represent by the symbol 1, is not an exact measure of the length proposed, there being a quantity even less than 1. Suppose for instance that

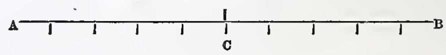
1 stands for the length ——
and that to be measured is 

then this last can neither be expressed by 3 nor 4; it contains the unit more than three times, and less than four times. To find a numerical expression for this length, we must therefore either assign a new value to 1, or discover some way of expressing it in terms of the value already assigned. This last is manifestly preferable, as it avoids the interminable confusion which would result from giving to our unit a value suited to every particular length to be measured; and it is, moreover, very simply done. The method is this: we suppose the primitive unit; that is, the quantity which we have agreed to call 1, to be broken down into a determinate number of equal parts, such that one of these parts shall be contained an exact number of times in the portion that is over. Thus in the foregoing instance, if the length denoted by 1 be divided into three equal parts, the portion of the second length which we have denoted by $x$, will be equal to two of them; for

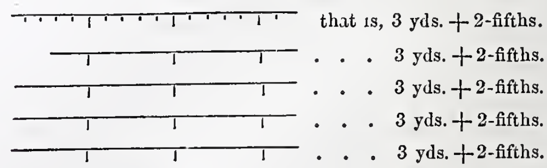



That is, 2 of the 3 parts into which 1 is divided are equivalent to the whole portion $x$. The parts into which the length 1 is here divided we call *thirds*, and as 2 of these thirds exactly coincide with the portion $x$, we say that that portion contains 2-*thirds*, which we agree to write $\frac{2}{3}$: *the under figure showing the number of equal parts into which the primitive* 1 *or* UNIT *of measure is divided, and the upper the number of these parts contained in the quantity which it was required to measure.* A number expressed in this way, we call a FRACTION, (that is, a broken number, or a number formed by taking *parts* of the unit; from *fractus*, broken,) when we wish to distinguish it from such numbers as 3, 7, 9; which we call *integers*, or *whole numbers*, as formed by the repetition of the unbroken unit.

2. As much depends upon our having a clear conception of the nature of a fraction, we may carry the explanation a step further. Suppose that we have this practical case. Divide 17 yards into five equal portions, and tell the magnitude of each portion. To proceed by our rule for division, we get a quotient 3, and remainder 2; but the question further requires that this remaining 2 yards be divided likewise into five equal portions, and that one of these portions be annexed to the quotient quantity, 3 yards. But this involves the question,—if 2 yards be divided into 5 equal parts, what is the magnitude of each part? According to the principle explained, the answer is $\frac{2}{5}$; and that this is true, is made obvious thus; suppose that the line A B represents two yards, and that each yard




is divided into five equal parts: the whole is thereby divided into *ten* new units, each of which is the fifth part of the original unit or yard. Now in order to find a fifth part of the whole length A B, it is manifestly enough to take *one-fifth* of A C + *one-fifth* of C B; but these parts are together as manifestly equal to *two* of the *fifths* of the unit A C. This we express by $\frac{2}{5}$, and is the quantity which we must add to 3 yards, to make up the fifth part of 17 yards. The five portions into which the 17 yards are divided may therefore be put down



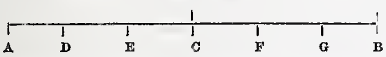

the sum of which is 15 yds. + 10-fifths = 17 yds.

3. The same kind of reasoning is applicable to the division of 17 gallons of rum, 17 acres of land, 17 bushels of corn, or 17 units of anything we please, into 5 equal parts; and therefore we conclude generally that the fifth part of 17 is 3 and $\frac{2}{5}$, which we might write $3 + \frac{2}{5}$ but for shortness usually write $3\frac{2}{5}$. But $\frac{2}{5}$ is the same as would be formed by writing the remainder 2 above, and the divisor 5 beneath, a horizontal line as directed by the rule for division, to denote the process that one number is to be divided by another; and, accordingly, we may regard every case of division so expressed as a fraction, and every fraction as

a division to be performed. In conformity with this view of the subject, $\frac{17}{5}$, $\frac{34}{10}$ $\frac{51}{15}$ are fractions; and the term fraction may even extend to whole numbers: for example, $\frac{17}{1}$, $\frac{34}{2}$, $\frac{51}{3}$, are fractions and all equal to 17.

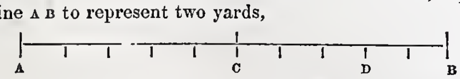
4. According to our new notation, which we thus find includes all our former ideas of number, and others besides, the part above the line is called the *numerator*, and that beneath, the *denominator*, and both of these are called *terms* of the fraction. The *numerator* takes its name from its expressing the *number* of parts of a certain kind that are taken; the *denominator*, from its giving *name*, as *sevenths*, *ninths*, to the parts into which the unit is divided. As long as the numerator is less than the denominator, the fraction is less than 1; thus, $\frac{19}{20}$ is less than 1: for the denominator is the unit divided into 20 parts, and we must therefore have 20 such parts to make 1; but the fraction $\frac{19}{20}$ shows that the quantity considered contains only 19 such parts. Similarly, $\frac{7}{11}$, $\frac{11}{12}$, $\frac{33}{35}$, are all less than 1, and are sometimes, for that reason, termed *proper fractions*. On the other hand, when the numerator is equal to, or exceeds the denominator, the fraction is equal to, or greater than 1; thus $\frac{5}{5}$ is equivalent to 1, for it is the fifth part of 1 repeated 5 times, or it is the magnitude of each of the parts which result from dividing 5 into 5 equal parts. Similarly, $\frac{4}{4}$, $\frac{9}{9}$, $\frac{12}{12}$, $\frac{29}{29}$, are all equal to 1 and consequently equal to each other. Again, $\frac{12}{7}$ is greater than 1: for the unit is here divided into 7 parts only, and the numerator consists of 12 or $7+5$ such parts, that is of a whole *unit* and *five-sevenths* of a unit over, or using signs $\frac{12}{7}=1\frac{5}{7}$. Expressions such as $\frac{5}{5}$ $\frac{12}{7}$, in which the numerator is equal to or exceeds the denominator, are usually called *improper fractions;* and when an expression consists of a whole number and a fraction, as $1\frac{5}{7}$, it is commonly called a *fractional* or *mixed number*.

5. There are two ways in which a fraction may be considered. If we have, for instance, such a fraction as $\frac{2}{3}$, we may regard it either as the third part of 2, or as twice the third part of 1. This is, indeed, plain from the foregoing discussion upon the division of 17 by 5; but in order to bring the principle more prominently before the mind, let the line A B be two yards;




and divide each of the yards A C and C B into three equal parts. Then because A E = E F = F B, and divide the length A B into three parts, A E is the third part of 2: it is therefore $\frac{2}{3}$. But A E is twice A D, and A D is the third part of one yard A C; and a third of a 1 is $\frac{1}{3}$. Therefore A E $=\frac{2}{3}$ is twice $\frac{1}{3}$. Hence to get a length equal to two-thirds of a yard, it makes no difference whether we divide *two yards* into three equal parts and take *one* of them, or whether we divide *one yard* into three equal parts and take *two* of them. The symbol $\frac{2}{3}$ is made to stand for both these operations, since they both lead to the same result. By the same sort of reasoning we conclude that *one-fifth* of *three*, and *three-fifths* of *one*, are identical and truly expressed by $\frac{3}{5}$; and the double interpretation may be extended to all other cases.

6. The meaning may appear somewhat ambiguous when the numerator of the fraction is greater than the denominator. For example, according to the latter interpretation, $\frac{8}{5}$ would mean that 1 is divided into five equal parts, and that 8 of them are to be taken. The explanation is, however, very easy: the case requires simply that as many units be each divided into fifths as will give more than 8 such parts, and that 8 of them are to be taken to form the numerator of the fraction. Thus, supposing the line A B to represent two yards,




divided each into five equal parts; the whole number of parts is 10, and of these we are to take 8, namely, A D, to form our fraction: and as each part is a fifth of one yard, 8 such fifths is truly expressed by $\frac{8}{5}$.

7. It is commonly reckoned necessary in arithmetical works to give a rule for finding the integers contained in an improper fraction. The necessity of such a rule has, however, been obviated by the explanation that every fraction may be regarded as a division to be performed. But if wanted it is this: *Divide the numerator by the denominator.* For example, how many units are there in $\frac{23}{6}$? Since $\frac{6}{6}=1$, it is plain that as often as $\frac{23}{6}$ contains $\frac{6}{6}$ so many units there will be. Now $23=6+6+6+5$; therefore,

$$\frac{23}{6}=\frac{6}{6}+\frac{6}{6}+\frac{6}{6}+\frac{5}{6}=1+1+1+\frac{5}{6}=3+\frac{5}{6} \text{ or } 3\frac{5}{6}$$

and this agrees with the rule; for $23\div 6$ give 3 for quotient and 5 for remainder; and the sixth part of 5 is $\frac{5}{6}$; therefore

$$23\div 6=3+\frac{5}{6} \text{ or } 3\frac{5}{6}$$

Similarly

| | |
|---|---|
| $\frac{39}{5}=39\div 5=7+\frac{4}{5}$ | $\frac{150}{14}=150\div 14=10\frac{10}{14}$ |
| $\frac{83}{11}=83\div 11=7+\frac{6}{11}$ | $\frac{307}{15}=307\div 15=20\frac{7}{15}$ |

8. The converse of this problem is the conversion of whole and mixed numbers into fractions, and is frequently needed. The rule is this: *Multiply the integral part by the given denominator and the product increased by the numerator of the fractional part (if there be any such part) is the numerator of the new fraction.*

As an example, express 3 in *fifths*. Since every 1 in 3 is $\frac{5}{5}$, therefore $3=\frac{5+5+5}{5}=\frac{5\times 3}{5}=\frac{15}{5}$.

Again, how many eighths in $7\frac{3}{8}$? In 7 there are, reasoning as before, $7\times 8$, or 56-*eighths;* therefore 7 and 3-*eighths* must contain $56+3$, or 59-*eighths;* consequently $7\frac{3}{8}=\frac{59}{8}$.

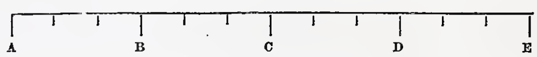
Similarly

| | |
|---|---|
| 7 expressed in ninths is $\frac{63}{9}$ | $9\frac{11}{12}$ expressed in twelfths is $\frac{119}{12}$ |
| $7\frac{1}{3}$ expressed in thirds is $\frac{22}{3}$ | 3 expressed in hundredths is $\frac{300}{100}$ |

These two processes are the inverse of each other, and mutually prove each others' results.

9. We come now to by far the most valuable property of a fraction. It is one, however, which we anticipated when we showed (Art. 14, page 142,) that the dividend and divisor may be either multiplied or divided by the same without affecting the quotient. As the greater part of the operations upon fractions have an immediate reference to the principle involved, we cannot be too particular in impressing it upon the mind of the student. It is the following:—

The value of a fraction is not altered by multiplying both its numerator and denominator by the same quantity. That is, $\frac{3}{4}$ is the same as $\frac{9}{12}$ or we shall obtain the result by dividing 1 yard into 12 parts, and taking 9 of them, and by dividing it into 4 parts and taking 3 of them. To prove this, let A E be a yard or any other definite length; divide it into 4 equal parts, A B, B C,




C D, and D E, and divide each of these parts into 3 equal parts; then A D is $\frac{3}{4}$. But it is also $\frac{9}{12}$, for the whole line is divided into 12 equal parts, and A D contains 9 of them; that is, we get the same length by dividing a yard into 12 equal parts, and taking 9 of them, as we get by dividing it into 4 equal parts, and taking 3 of them. We have, therefore, no difficulty in concluding generally that $\frac{3}{4}$ and $\frac{9}{12}$, are the same thing. It follows from this that every fraction admits of innumerable alterations in its form, without suffering any change of value.

Thus

$$\frac{1}{2}=\frac{2}{4}=\frac{3}{6}=\frac{4}{8}=\frac{5}{10}=\frac{6}{12}=\frac{7}{14}=\frac{8}{16}=\&c.$$

$$\frac{2}{7}=\frac{4}{14}=\frac{6}{21}=\frac{8}{28}=\frac{10}{35}=\frac{12}{42}=\frac{14}{49}=\frac{16}{56}=\&c.$$

On the same principle, it is shown that the terms of a fraction may both be divided by any number without any alteration of its value. This hardly needs demonstration: for $\frac{3}{4}$ and $\frac{9}{12}$ are the same, and $\frac{3}{4}$ is made from $\frac{9}{12}$, by dividing both the numerator and denominator by 3.

10. Though the two fractions $\frac{3}{4}$ and $\frac{9}{12}$ are the same in value, and either of them may be used for the other without error, yet

the first is more convenient than the second, not only because we have a clearer idea of *three-fourths* of a yard than of *nine-twelfths* of it; but the numbers in the first being smaller, they are more conveniently added, subtracted, multiplied, or divided. It is therefore useful, when a fraction is given, to find out whether its terms have any common divisor or measure. The method of doing this was explained in our last chapter; where it was likewise shown that when two numbers are divided by their greatest common measure, the quotients are *prime* to each other. When the terms of a fraction are reduced to this condition; that is, incapable of being both measured by any number greater than 1, the fraction is then said to be reduced to its *lowest terms,* and cannot be expressed more simply or by any fraction having a smaller numerator and denominator. From all this it appears that a fraction is reduced to its lowest terms when its numerator and denominator are divided by their greatest common measure, or have all their common factors expunged.

It frequently happens that the greatest common measure is evident on inspection, as in the following instances where the common factors are accented :—

$$\frac{8}{12}=\frac{2\times 4'}{3\times 4'}=\frac{2}{3} \qquad \frac{9}{81}=\frac{1\times 9'}{9\times 9}=\frac{1}{9} \qquad \frac{28}{35}=\frac{4\times 7'}{5\times 7'}=\frac{4}{5}$$

$$\frac{12}{48}=\frac{1\times 12'}{4\times 12'}=\frac{1}{4} \qquad \frac{14}{21}=\frac{2\times 7'}{3\times 7'}=\frac{2}{3} \qquad \frac{24}{21}=\frac{8\times 3'}{7\times 3'}=\frac{8}{7}$$

When the terms of the fraction are large numbers, it then becomes necessary to apply the rule for finding the greatest common measure of two numbers in order to eliminate the common factor of the terms. The following are instances :—

$$\frac{2433}{13787}=\frac{3\times 811}{17\times 811'}=\frac{3}{17} \qquad \frac{8888}{403596}=\frac{22\times 404'}{999\times 404'}=\frac{22}{99}$$

$$\frac{1397}{2921}=\frac{11\times 127'}{23\times 127'}=\frac{11}{23} \qquad \frac{13786}{93208}=\frac{113\times 122'}{764\times 122'}=\frac{113}{764}$$

Where the terms of the fraction are already in factors, any one factor in the numerator may be divided or struck out, provided the same is done with some one factor in the denominator. --*Principle,* the same as before.

$$\frac{4\times 7\times 5}{8\times 6\times 10}=\frac{1'\times 7\times 1}{2'\times 6\times 2'}=\frac{7}{2\times 6\times 2}=\frac{7}{24} \qquad \frac{21\times 16\times 4}{14\times 32\times 8}=\frac{3}{8}$$

$$\frac{12\times 18\times 33}{18\times 24\times 11}=\frac{2'\times 3'\times 3'}{3'\times 4'\times 1'}=\frac{1'\times 1'\times 3}{1'\times 2'\times 1'}=\frac{3}{2} \qquad \frac{7\times 25\times 30}{28\times 35\times 100}=\frac{3}{56}$$

11. Since the relative magnitudes of fractions depend upon two numbers, it is not always easy, at first view, to pronounce which of two quantities so expressed is the greater, especially if the terms are high numbers. For instance, take $\frac{4}{5}$ and $\frac{13}{15}$. Before we can compare their values, or express their sum or difference by a single number, we must effect such a change on one or both of them, that their component units shall be the same. Let the terms of $\frac{4}{5}$ be multiplied by 15, and the terms of $\frac{13}{15}$ by 5, then $\frac{4}{5}$ becomes $\frac{60}{75}$, and $\frac{13}{15}$ becomes $\frac{65}{75}$, and as these new fractions have the same values as those given (art. 9.) and express parts of the same unit, *for the denominator in both is the same,* we are able to pronounce on their relative magnitudes, and as we shall afterwards see, are able to find their sum or difference with comparative facility.

To show how this is done, we shall take an example. Let the proposed fractions be $\frac{1}{2}$, $\frac{3}{4}$, $\frac{5}{6}$, $\frac{2}{3}$. Multiply both terms of $\frac{1}{2}$ by $4\times 6\times 3$; both terms of $\frac{3}{4}$ by $2\times 6\times 3$; both terms of $\frac{5}{6}$ by $2\times 4\times 3$; both terms of $\frac{2}{3}$ by $2\times 4\times 6$; then it appears that

$$\frac{1}{2} \text{ is } \frac{1\times 4\times 6\times 3}{2\times 4\times 6\times 3} \text{ or } \frac{72}{144} \qquad \frac{5}{6} \text{ is } \frac{5\times 2\times 4\times 3}{6\times 2\times 4\times 3} \text{ or } \frac{120}{144}$$

$$\frac{3}{4} \text{ is } \frac{3\times 2\times 6\times 3}{4\times 2\times 6\times 3} \text{ or } \frac{108}{144} \qquad \frac{2}{3} \text{ is } \frac{2\times 2\times 4\times 6}{3\times 2\times 4\times 6} \text{ or } \frac{96}{144}$$

We have thus succeeded in making all the given fractions take the same denominator, 144, and the method by which it is done is as follows :—

*Multiply each numerator by all the given denominators except its own, for the numerator of the equivalent fraction, and take the product of* ALL *the denominators for its denominator.*

This is the rule commonly given; and it is at once obvious, that it must always succeed in forming a new set of fractions, having a common denominator. But on examining the resulting fractions of the foregoing example, we find that all the numerators and the common denominator are divisible by 12; and we have already shown that this division does not affect their value. Making therefore this division, we get

$$\frac{6}{12} \text{ instead of } \frac{72}{144} \qquad \frac{10}{12} \text{ instead of } \frac{120}{144}$$

$$\frac{9}{12} \;\ldots\; \frac{108}{144} \qquad \frac{8}{12} \;\ldots\; \frac{96}{144}$$

These are likewise fractions equivalent to those giving and having a common denominator; but the common denominator is a much smaller number, and therefore they are a simpler answer to the question than the first fractions found. Our first object is to find equivalent fractions having a common denominator; but as a matter of course, it is of great importance that the denominator be as small as possible, and this is always the case when the numerators and this denominator have no common measure. Again, the common denominator which fulfils these conditions, is the least common multiple of all the denominators given, and is found as explained in our last Chapter, (Art. 10.) The method of proceeding will be best understood by an example. Let the given fractions be

$$\frac{1}{2} \quad \frac{2}{3} \quad \frac{3}{4} \quad \frac{7}{6} \quad \frac{9}{10} \quad \frac{5}{12} \quad \frac{17}{18} \quad \frac{8}{21}$$

Find the least common multiple of these denominators: it is 1260, and the equivalent fractions to be found, cannot obviously have a less common denominator than this, and it needs not be greater. Taking it therefore as the denominator wanted, we find a set of multipliers for the numerators of the given fractions, simply by dividing the multiplier by all the denominators in succession.

Thus $1260\div 2=630 \quad 1260\div 4=315 \quad 1260\div 10=126$
$1260\div 3=420 \quad 1260\div 6=210 \quad 1260\div 12=105$
$1260\div 18=70 \quad 1260\div 21=60$

We now multiply every given numerator by the result of its denominator in the preceding list, for the numerator of the equivalent fraction, and write 1260 for the common denominator of all, as follows :—

$1\times 630= 630$; therefore $\frac{1}{2}$ is $\frac{630}{1260}$ | $9\times 126=1134$; therefore $\frac{9}{10}$ is $\frac{1134}{1260}$

$2\times 420= 840$; therefore $\frac{2}{3}$ is $\frac{840}{1260}$ | $5\times 105=525$; therefore $\frac{5}{12}$ is $\frac{525}{1260}$

$3\times 315= 945$; therefore $\frac{3}{4}$ is $\frac{945}{1260}$ | $17\times 70=1190$; therefore $\frac{17}{18}$ is $\frac{1190}{1260}$

$7\times 210=1470$; therefore $\frac{7}{6}$ is $\frac{1470}{1260}$ | $8\times 60=480$; therefore $\frac{8}{21}$ is $\frac{480}{1260}$

The following instances may be managed exactly in the same way, and will afford sufficient exercise in the rule, should they be worked over with care.

| Fractions given. | | | | | | Reduced to a common Denominator. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $\frac{1}{2}$ | $\frac{2}{3}$ | $\frac{3}{4}$ | $\frac{1}{6}$ | $\frac{3}{8}$ | $\frac{5}{12}$ | $\frac{12}{24}$ | $\frac{16}{24}$ | $\frac{18}{24}$ | $\frac{4}{24}$ | $\frac{9}{24}$ | 1[illegible]/24 |
| $\frac{1}{3}$ | $\frac{2}{7}$ | $\frac{3}{14}$ | $\frac{12}{21}$ | $\frac{3}{4}$ | | $\frac{28}{84}$ | $\frac{24}{84}$ | $\frac{18}{84}$ | $\frac{48}{84}$ | $\frac{63}{84}$ | |
| $\frac{3}{4}$ | $\frac{5}{9}$ | $\frac{9}{10}$ | $\frac{7}{12}$ | $\frac{1}{18}$ | | $\frac{135}{180}$ | $\frac{100}{180}$ | $\frac{162}{180}$ | $\frac{105}{180}$ | $\frac{10}{180}$ | |
| $\frac{1}{2}$ | $\frac{1}{3}$ | $\frac{1}{4}$ | $\frac{1}{5}$ | $\frac{1}{6}$ | | $\frac{30}{60}$ | $\frac{20}{60}$ | $\frac{15}{60}$ | $\frac{12}{60}$ | $\frac{10}{60}$ | |
| $\frac{5}{8}$ | $\frac{7}{12}$ | $\frac{11}{18}$ | $\frac{9}{20}$ | | | $\frac{225}{360}$ | $\frac{210}{360}$ | $\frac{220}{360}$ | $\frac{162}{360}$ | | |
| $\frac{1}{9}$ | $\frac{3}{5}$ | $\frac{7}{15}$ | $\frac{5}{6}$ | $\frac{16}{24}$ | $\frac{11}{27}$ | $\frac{120}{1080}$ | $\frac{648}{1080}$ | $\frac{504}{1080}$ | $\frac{900}{1080}$ | $\frac{855}{1080}$ | $\frac{440}{1080}$ |

# ANATOMY AND PHYSIOLOGY.

## CHAPTER VII.

### THE MUSCLES AND MUSCULAR ACTION.—*Continued.*

I WILL now take a short review of the uses of the principal portion of the thirty-one muscles which I have last described. 1st, The palmaris longus, the flexor carpi radialis, and flexor carpi ulnaris, are the three principal flexors or benders of the wrist. 2d, The extensor carpi ulnaris, the extensor radialis longior, and extensor radialis brevior, are the three principal extensors or stretchers

of the wrist. 3d, The chief pronators of the hand are, 1st, the pronator teres; 2d, the pronator quadratus; and 3d, the flexor muscles. 4th, The three supinators of the hand are, 1st, the supinator longus; 2d, supinator brevis; and 3d, the biceps. 5th, The three extensors of the fingers are, 1st, extensor communis digitorum; 2d, extensor primi digiti; and 3d, extensor minimi digiti. 6th, The three extensors of the thumb are, 1st, the extensor primus pollicis; 2d, extensor secundus pollicis; and 3d, extensor tertius pollicis. 7th, The three flexors of the thumb, are, 1st, flexor digitorum sublimis; 2d, flexor digitorum profundus; and 3d, the flexor longus pollicis. All the muscles that arise from the inner knob or condyle of the humerus or arm-bone, are flexors; but from the external condyle, they are extensors; those inserted into the radius turn the wrist, by rolling the radius on the ulna. Their mechanism and action are beautiful, simple, and perfect. We will now pass on to the muscles of the ribs, and respiration.

The whole of the back is covered with strong muscles related to the arm, ribs, and spine; but the muscles appropriated to the ribs, which perform no other function than respiration, are, 1st, The serratus posticus superior, which comes from the neck, extends over the ribs and pulls them downward. 2d, The serratus inferior posticus, which comes from the vertebræ of the loins, lies flat on the lower portion of the back, and pulls the ribs downwards. 3d, The twelve levatores costarum, which arise from the transverse processes of each vertebræ of the back; and each muscle going down to the rib below, raises it up when in action. 4th, The intercostal muscles, external and internal, fill up the spaces, crossing each other betwixt the ribs, and raise and depress the chest in respiration; to these may be added, the triangularis sterni, a muscle that lies within the chest, and pulls the ribs downward. The muscles of the ribs are appropriated to respiration, and unite their functions with the diaphragm and muscles of the abdomen; but in coughing, sneezing, speaking, smelling, &c., there are other muscles also brought into action besides these, belonging to the locally affected or irritated parts; and, whether individually or combined, display the infinite goodness, power, and wisdom, of our great Creator, in planning and accomplishing the mechanism and utility of the human body.

There are seven posterior muscles of the head and neck yet undescribed; 1. Splenius; 2. Complexus; 3. Trachelo-mastoideus; 4. Rectus minor; 5. Rectus major; 6. Obliquus-superior; 7. Obliquus inferior. The splenius, acting singly, turns the head obliquely to one side; but when both act, they pull the head downward. The complexus and trachelo-mastoideus, rectus major and minor, perform nearly the same action as the splenius. The obliquus superior and inferior, perform the short quick turnings of the head; all these muscles, more or less assist each other.

We will now proceed to the posterior muscles of the trunk, which form the greater portion of the fleshy substance of the back. 1. Quadratus lumborum, keeps the trunk erect, inclines it to one side, turns it on its axis, pulls down the ribs, and assists respiration; 2. Longissimus dorsi keeps the trunk erect, and bends the spine backward; 3. Sacro-lumbalis, takes a firm hold of the ribs, and not only pulls them down, but also assists in raising the trunk; 4. Cervicalis descendens, turns the neck to one side and bends it; 5. Transversalis colli lies between the trachelo-mastoideus and cervicalis descendens.

The surface of the back, betwixt the bulge of the ribs on each side of the chest, consists of innumerable hollows, processes, and points of bone, and is tied from point to point, and its hollows filled, with unequal bundles of tendon and flesh. The 1st bundle is divided into two sets, called spinalis cervicalis, and spinalis dorsi. It lies along the whole length of the neck and back, and raises the spine. The 2d bundle is called semi-spinalis dorsi; the 3d, multifidus spinæ, keeps the spine from bending too much forward; the 4th and 5th, inter-transversalis, and inter-spinalis, are useful in assisting us to perform the lateral and twisting motions of the loins. There are other two bundles called inter-transversalis-cervicis, and priores-lateralis, which complete the total number; all these muscles render the back firm, smooth, elastic, thick, and powerful, but especially the spine, which they clothe with flesh.

There are still other five muscles, lying on the fore part of the head and neck, which I may briefly mention, as they complete the catalogue of the muscles belonging to the spine: 1st, Rectus internus capitis major; 2d, Rectus internus minor; 3d, Rectus capitis lateralis; 4th, Longus colli; 5th, Scalenus. The first four muscles pull the neck to one side when acting single; but when acting double, they bend down the neck and head. The scalenus, in asthmatic patients, throws the head backward, that the chest may be more powerfully raised in coughing.

The muscles of the abdomen or belly are five on each side. 1st, The obliquus externus on each side, covers all the abdomen with its fleshy belly, and also the forepart of the abdomen with its white expanded tendon. Its fibres run obliquely from above, downward, and inward. 2d, The obliquus externus arises chiefly below in the haunch-bone, and all its fibres run from below upward. 3d, The transversalis lies under all the other muscles next the abdominal cavity. Its fibres run across and round the abdomen. 4th, The rectus runs on the fore part of the belly, in a straight line from the os pubis, or share-bone, to the sternum, or breast-bone. 5th, The pyramidalis is named after its shape, being pyramidal in form. It is a small neat conical muscle, arising from the os pubis, and having its apex turned upward. In some subjects this muscle is wanting.

These five abdominal muscles make the external covering for the belly, and by taking a firm hold of the pelvis (or basin) and trunk, they support and contain the bowels. They also bend and turn the trunk, and fix it firmly for the stronger action of the limbs. They keep the body steady in raising weights, bearing loads, and, alternately with the diaphragm or midriff, (an internal muscle which separates the abdomen from the chest,) they perform respiration. When the diaphragm presses down the bowels and enlarges the thorax or chest, we perform inspiration by drawing in our breath; when the abdominal muscles react and push back the diaphragm, the chest is compressed, and expiration, or letting out a breath, is accomplished. The abdominal muscles assist in emptying the bowels, expelling the child from the womb, and promote the circulation of the blood. But sometimes under these accumulated labours they give way, and burst frequently near the groin; and the bowels, protruding through the interstices of the muscular fibres, and enlarged natural passages, form hernia, or rupture, which is a very frequent attendant on old age—especially in men who have often endured violent exercise, such as straining, pulling, raising heavy weights, and carrying oppressive loads.*

The two oblique muscles on one side, when in action, turn the body on its axis. But when they act on both sides, they co-operate with the rectus muscle in flattening the belly, and bending the body. The transverse muscles tighten the linea alba, a tendon which I am now about to describe. The recti muscles pull the ribs downward in breathing, flatten the body, and bend it forward.

I will now briefly notice a few other parts of the abdomen before I conclude the present essay. 1st, The linea alba is the common meeting of all the white thin flat tendons of the abdominal muscles in the centre of the belly, and forms the point toward which they all act. 2d, The linea semilunaris, is a white circular line, produced by the meeting of all the tendons of the abdomen on the edge of the rectus, to form its sheath, and is called the sheath of the rectus muscle. 3d, The umbilicus, or navel, is an opening in the centre of the belly, or the middle of the linea alba, through which the nourishing vessels have passed between the fœtus in utero, and the mother. These vessels in the adult degenerate into a ligament, which sometimes bursts, and forms umbilical hernia by the protrusion of the bowels. 4th, The inguinal ring of the abdominal muscles is an opening near the lower part of the belly above the pubis and groin, through which the spermatic cord passes in men, and the round ligament of the womb in women. It is formed by an oblique split in the tendon, commencing about an inch and a half above the pubis; and the spermatic cord in males (which passes through it), is formed by the vessels belonging to the testicle. 5th, The cremaster muscle is a thin slip of fibres coming from the internal oblique muscle, for suspending the testicle and drawing it up. It generally grows more fleshy with advancing old age. It is very large in dogs, and other animals in whom the weight of the testes require powerful support. Umbilical hernia, or rupture at the navel, is more frequent in females than

* I lately saw a case of abscess in an old man's groin, which a parochial surgeon mistook for rupture, and caused a truss to be placed over it. When the abscess was opened, nearly a pint of matter was discharged.

males; because the umbilical opening is slowly dilated in pregnancy and admits the bowels to protrude. Inguinal hernia, or rupture at the abdominal ring, is more frequent in men than women, because the round ligament of the womb being smaller than the spermatic cord, the inguinal ring is therefore closer and firmer in women than men. There seems to be a hereditary predisposition to hernia in certain families; and in these cases it is almost impossible to prevent the protrusion of the bowels from the most trivial causes in childhood.

The diaphragm, or interseptum, is an internal transverse vaulted partition betwixt the abdomen and chest; it is not only vaulted in the middle, but rises as high anteriorly as the breast-bone, where it commences; while its lower and back parts begin almost as low as the pelvis, and from the false ribs and the vertebræ of the loins; and although it is convex towards the chest, and concave towards the belly, yet it becomes almost plain when it presses against the abdominal muscles in inspiration, but resumes its convexity, when by their reaction it is pushed back again into the chest in expiration. This alternate action and reaction constitute respiration or breathing; strictly speaking, however, there are two diaphragms—a greater before, and a smaller behind; in the centre betwixt them is a strong triangular tendon, and in the fleshy and tendinous fibres are several natural openings for the transmission of blood-vessels, ducts, and nerves, betwixt the abdomen and the chest.

Besides the important function of respiration, the diaphragm is not only useful in assisting to discharge fæcal matter and urine, from the bowels and bladder, but to expel the fœtus from the womb in parturition. Vomiting, hiccuping, yawning, crying, laughing, coughing, sighing, weeping, and indeed every audible emotion of joy and fear are diaphragmatic actions; and the celebrated Haller very justly remarks, "that the diaphragm is the noblest muscle after the heart."

The power of the muscles, the rapidity and durability of their action, are in some animals very extraordinary. The smallest common flea leaps with ease many hundred times the length and height of its body, by the agile power of the muscles of its legs. The wings of the humming bee move with such astonishing rapidity, that each muscular motion is imperceptible to the most discriminating eye. The lady-bird will fly 480 million times the length of its body in twenty-four hours. The eagle will fly fifty-four miles in an hour, and the canary-falcon 1125 miles in twenty-four hours. The antelope will run a mile in a minute; the elk a mile and a half in seven minutes; and some men have travelled a hundred miles in twenty-four hours. The human heart and arteries, beating at the rate of 64 per minute—pulsate 92,160 times every twenty-four hours; and often continue to beat without intermission and fatigue, for eighty or ninety years. The middle-coat of the arteries, and the entire heart, are muscular; and pulsation is accomplished by their elastic power, stimulated by the circulating blood.

The power and rapidity of muscular action do not always depend on the comparative magnitude and strength of the muscles. The sloth is many thousand times larger than the flea, yet the sloth will only travel fifty paces per day—a journey which the flea will perform with a few wonderful leaps. The worm is many hundred times larger than the ant, yet the former will only crawl a few inches per minute, while the latter is almost constantly in rapid exercise, and carries heavy loads to his nest. Although some sluggish animals have naturally very little muscular rapidity when performing locomotion, yet if wounded or irritated, their muscles are thrown into violent action, and convulsively move with rapidity and power. The worm that crawls only six inches a minute, when naturally left to the sluggish movements of its muscles, will writhe and fling its body to and fro when wounded, and dash itself on the ground with rapidity and violence. When muscles are spasmodically contracted, they are rigid and painful; and when cramp seizes our limbs, we feel the affected muscles stiff, hard, and inflexible as rods of iron. The pain is excruciating, and nothing can alleviate its severity, but the cessation of spasm. This intense suffering is produced by the muscular fibres pressing spasmodically on the nerves that ramify in the affected muscles, and supply their fibres with sensibility and nervous power. The middle coat of the stomach and bowels is muscular, and every person knows how speedily death is sometimes produced by its painful spasms. We ought never, by overstrained exertion, to injure our muscles. Insupportable fatigue sometimes ruptures their fibres, destroys their action and induces lameness. The muscles are perfectly fitted to perform every useful motion for which the Creator has designed them. If we employ them wrongfully, we injure their utility, thwart our Creator, and incur the penalty of wilfully violating the laws of nature.

We shall proceed to describe the muscles of the inferior parts of the body, and the lower extremities, in our next chapter, and finish the muscular system.

# GEOLOGY.

## CHAPTER VII.

### VOLCANOES.

Whether the remarkable increase of temperature, experienced in descending beneath the surface of the earth, is the effect of radiation from a molten mass of incandescent matter, or whether it is occasioned by electric currents in the crust of the earth itself, is matter of dispute. Mr. Lyell favours the last hypothesis. "Some portions of earthy compounds," he says, "are daily resolved into their elements, and these on being set free are always passing into new combinations. These processes are almost always accompanied by evolution of heat, which is intense in proportion to the rapidity of the combinations. At the same time there is a development of electricity. It is well known that a mixture of certain materials sunk in the ground and exposed to moisture, gives out sufficient heat to pass gradually into a state of combustion, and to set fire to any bodies that are near. Let a large quantity of clean iron filings be mixed with a still larger proportion of sulphur, and as much water as is necessary to make them into a firm paste; let the mixture be then buried in the earth, and the soil pressed down firmly upon it. In a few hours it will warm and swell so as to raise the ground, sulphureous vapours will make their way through the crevices, and sometimes flames will appear. There is rarely an explosion; but when this happens, the fire is vivid; and if the quantity of materials is considerable, the heat and fire will continue for a long time."

Instead, therefore, of referring volcanic action to the existence of an original central heat, it has been inferred that it may result from changes similar to that referred to, going on constantly in the crust of the earth. It has also been considered as probable, that the contact of water with the bases of the earths and alkalies in the subterranean regions may produce intense heat, and this theory is also supported by the fact, that volcanoes are in general situated near the coast. The hypothesis is familiarly illustrated by bringing a piece of potassium or sodium into contact with any moist substance: a rapid decomposition of the water ensues with the evolution of intense heat—the oxygen combining with the metal to produce potash or soda, according as the base of the one or the other is employed. A similar effect accompanies the action of water on the other metallic bases. But whether this affords a sufficient explanation of volcanic action, is a question upon which we are not yet prepared to give a decision. The fact is, however, before us; and whatever may be the cause or causes which produce volcanic phenomena, the burning mountain and the earthquake have at all times been objects of intense interest. We propose, therefore, to give the history of a few volcanic eruptions in various parts of the world, as narrated by Lyell and other naturalists.

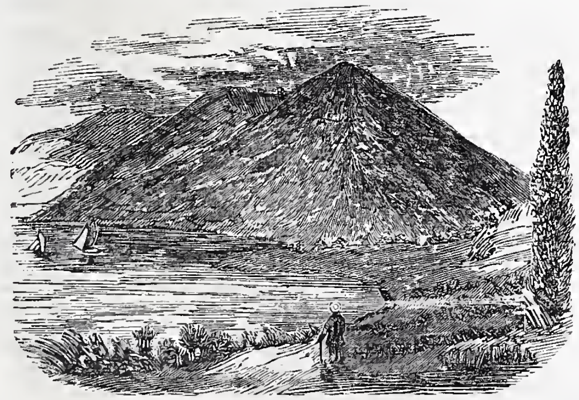
A volcano generally consists of a cone-shaped hill, with a wide crater or chasm at its summit, from which issue flame and smoke, and in the times of great activity, rivers of burning lava, and showers of stone and ashes. The quantity of matter poured out is various. Sometimes it overspreads considerable tracts of the adjacent territory, and, when consolidated, forms a stratum of rock to the depth of many feet. Sometimes the showers of dust and stones are immense,—so much so, in fact, as in the cases of Pompeii and Herculaneum, to bury whole cities. The eruption of a volcano generally commences with a tremendous explosion, which is succeeded by others less loud, and the escape of gas and vapour from the mouth of the crater. Large fragments of solid

rock, and masses of lava, are projected in these discharges, some of which are thrown upward in a perpendicular direction, and fall back into the mouth of the crater, from which they are again discharged. By these means they are often broken into powder and mingled with the surrounding atmosphere, producing the appearance of dense clouds of smoke. The lava then rises to the vent of the mountain, and soon finds egress, sometimes from the crater at the summit of the mountain, or from openings in its sides—which is generally the case when the mountain is very high. The noises, which frequently resemble the discharge of artillery, are not so frequent when the lava is issuing from the mountain. When the detonating becomes less frequent, rumbling sounds are heard as of the rushing of many waters; after which the mountain gradually sinks into a quiescent state, as if wearied with the work of convulsion and destruction.

In ancient times, Vesuvius, which is situated on the bay of Naples, had a cone of a very regular form, terminating not as now in two peaks, but with a flattish summit. "The sides of the mountain," says Mr Lyell, "were richly cultivated, and at its base stood the once populous cities of Pompeii and Herculaneum. The first principal eruption of Vesuvius, in the Christian era, occurred in the year 79,—the year in which the cities, above mentioned, were so utterly overwhelmed, that their very sites remained unknown till the last century, when in digging the ground the chimneys of the houses were discovered. Considerable portions of both cities have been excavated, and many curious facts described, illustrative of the architecture and arts of the first century.—(*Vide* page 85.)

Nearly one-fourth of Pompeii has already been exposed to view, both the public and the private buildings bearing testimony to the catastrophe. The walls are rent, and in many places traversed by fissures still open. Columns are lying on the ground only half-hewn from their blocks of travertin, and the temple for which they were designed is only half repaired. In some few places the pavement had sunk, but in general it was undisturbed. This consists of large irregular flags of lava, neatly joined together, in which the carriage wheels have often penetrated an inch-and-a-half deep. A very small number of skeletons have been discovered in either city, showing that the inhabitants had time to escape. Those, however, of two soldiers were found chained in the stocks; and in the vaults of a country house, in the suburbs, were found the skeletons of seventeen persons, who appear to have fled thither to escape from the shower of ashes. They were found in an indurated taffa, and in this matrix is preserved a perfect cast of a woman with a child in her arms. Though her form was imprinted on the rock, nothing but the bones remained. To these a chain of gold was suspended, and on the fingers of the skeleton were rings with jewels. Against the side of the same vault were ranged a long line of earthen jars.

In 1539, a volcanic hill called Monte Nuova was formed in the bay of Baiæ, near Naples. It rose to the height of 440 feet, and attained a circumference of a mile and a half. The phenomena attending the formation of this hill have been described by several



Monte Nuova

writers, who lived at the time, and from them the following statement is made. Earthquakes had been very frequent for two years previous; but on the 27th and 28th of September, not less than twenty shocks were felt in twenty-four hours. On the 29th, a gulf opened in the ground, and a large fissure or rent approached the small town of Tipergola, which formerly existed on the site of the Monte Nuova. From this opening there issued a tremendous noise, accompanied with flame, and discharges of pumice stones, blocks of unmelted lava, and ashes, mixed with water. The town was overwhelmed with the ashes, which fell in immense quantities, even at Naples, a distance of several miles. The sea retired for about 200 yards, and left a portion of its bed dry. The whole coast, for a distance of some miles, was upraised many feet above the bed of the Mediterranean. The new-formed hill presents the appearance of a truncated cone. The crater at its summit is 421 feet deep.

Vesuvius remained in a state of tranquillity for nearly a century after the formation of Monte Nuova. The following description of the interior of Vesuvius is given by one Bracini, who visited it not long before the great eruption, which occurred in 1631:—

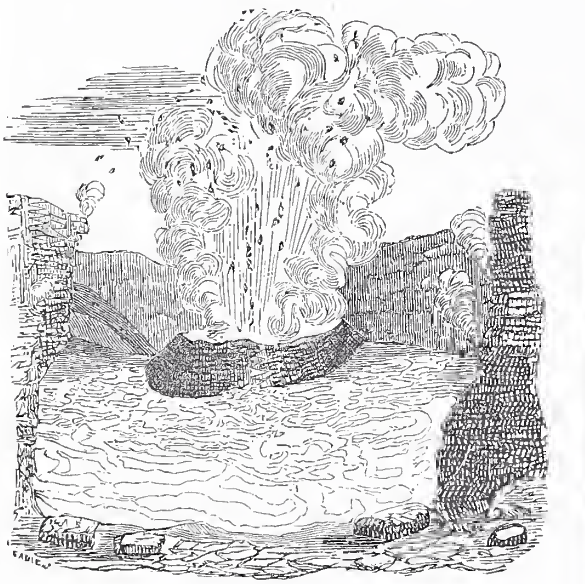
"The crater was 5 miles in circumference, and about 100 yards deep; its sides were covered with brushwood; and at the bottom there was a plain, covered with ashes, on which cattle grazed, and wild boars frequently harboured in the woody parts. In one part of the plain were four small pools; one filled with hot and another with bitter water; another salter than the sea, and a fourth hot but tasteless. But at length these forests and grassy plains were consumed, being suddenly blown into the air, and their ashes scattered to the winds." In 1631, according to Mr Lyell, seven streams of lava poured at once from the crater, and overflowed several villages on the flanks and foot of the mountain. Resina, partly built over the ancient site of Herculaneum, was consumed by the fiery torrent. "Great floods of mud were as destructive as the lava itself—no uncommon occurrence," says he, "during those catastrophes; for such is the violence of rains produced by the evolution of watery vapour, that torrents of water descend the cone, and, becoming charged with impalpable volcanic dust, and rolling along loose ashes, acquire sufficient consistency to deserve their ordinary appellation of aqueous lavas."

Sir Wm. Hamilton, in describing an eruption of Vesuvius in 1779, mentioned that jets of liquid lava, mixed with stones and scoriæ were thrown up to the height of at least ten thousand feet, having the appearance of a column of fire. Some of these were directed by the winds towards the town of Ottaiana, and some of them still red hot and liquid, falling almost perpendicularly on Vesuvius, covered its whole cone, part of the mountain of Somno, and the valley between them. The falling matter, being nearly as vividly inflamed as that which was continually issuing fresh from the crater, formed with it one complete body of fire, which could not be less than two miles and a half in breadth, and of the extraordinary height above mentioned, and cast a heat to the distance of, at least, six miles around it. In an eruption of the same mountain, which took place in the year 1793, Dr Clark, who was an eye-witness, tells us that millions of red hot stones were shot into the air full half the height of the cone itself, and then bending, fell all round in a fine arch. The same author has also described the different appearances of the lava, at its source, and at some distance from it when it had descended into the vale below. At the point where it had issued in 1779, from an arched chasm in the side of the mountain, the vivid torrent rushed with the velocity of a flood. It was in perfect fusion, unattended with any scoriæ on its surface, or any gross material not in a state of complete solution. It flowed with the translucency of molten gold, in regular channels, cut finer than art can imitate, and glancing with all the splendour of the sun. "Sir Wm. Hamilton had conceived, that no stones thrown upon a current of lava could make impression. I was soon convinced," says Dr Clark, "of the contrary,—light bodies, indeed, of 5, 10, or 15 pounds weight, made little or no impression even at the source; but bodies of 60, 70, or 80 pounds, were seen to form a kind of bed on the surface and then disappeared. If I were to describe," continues the author, "the manner in which it acted upon the lava, I should say it was like a loaf of bread thrown into a bowl of thick honey, which gradually works itself into the heavy liquid, and then slowly sinks to the bottom."

"The lava at a small distance from its source acquires a darker tint upon its surface, is less easily acted upon; and, as the stream widens, the surface having lost its state of perfect solution, grows harder and harder, and cracks into innumerable fragments of very porous matter, to which they give the name of scoriæ—the appearance of it leading many to suppose that it proceeded thus from the mountain. There is, however, no truth in this. All lava, at its first exit from its native volcano, flows out in a

liquid state, and all equally in fusion. The porous appearance of the scoriæ is to be attributed only to the action of the external air, and not to any difference in the materials which compose it; since any lava whatever, separated from its channel, and exposed to the external air, immediately cracks, becomes porous, and alters its form." The same author acquaints us, that, at the bottom of the mountain, the whole current resembled nothing so much as a heap of unconnected cinders from an iron foundry. These torrents flowing from time to time, naturally form a series of strata, as is manifested in the cone of the mountain, the eruption of which we have been describing. In the rents of this stratification, masses of volcanic matter are sometimes projected, and sometimes poured in from above. Eruptive ashes are often scattered round the country to considerable distances; and a large quantity of this product falling into the sea, is swept into the deep by torrents. During the intervals between the eruptions, the tuffaceous matter becomes mixed with other kinds of sediments, with shells and coral, and forms rocks of a mixed character, such as taffa, and volcanic conglomerates, cemented together.

We have been thus particular with respect to Vesuvius, because in it we meet with features of almost all other volcanic phenomena, and because our limits will not permit the same detail respecting the others.



Crater of Vesuvius.

We cannot, however, in justice to the subject, avoid noticing some of the facts connected with a few other volcanoes, particularly Etna.

The summit of this mountain is about 11,000 feet above the level of the sea, and the base is 87 miles in circumference. Round the base of the mountain is one of the most fertile countries in the world, well cultivated, numerously inhabited, and adorned with the richest luxuriance. The vine, the olive, and the fig-tree, grow there, and many of the richest aromatic herbs. In ascending from the fertile, we reach the woody region which encircles the mountain. This consists of immense forests which afford pasturage for numerous flocks. The trees are the oak, the chesnut, the pine, the beech, and the cork,—the two latter forming groves of great magnificence and beauty. From the woody we ascend to the desert region, which presents nothing but a bleak barren district, overlaid with lava and ashes. Over this plain, from which sulphureous vapours continually issue, the mountain ascends to the height of about 1100 feet. But the most interesting feature of this volcano is the immense number of cone-shaped hills which flank its woody and lower regions. About 80 of these secondary volcanoes are of considerable dimensions, some of them measuring from 400 to 700 feet in height. These immense cones are produced by lateral eruptions of the mountain, and are sometimes almost obliterated by the floods of lava which occasionally surround their base. The crater of the volcano is from $2\frac{1}{2}$ to 4 miles in circumference, and from 600 to 800 feet deep.

The mountain is situated in that division of Sicily which is called Val Demone, in allusion to the old superstitious notion, that the flames and smoke of Etna ascend from the region of demons. To obtain a just idea of this, the largest volcano in Europe, it may not be amiss to notice a few of the geological features of the country.

"The Val di Noto, or southern division of Sicily is composed of a series of tertiary strata, associated with lavas and other volcanic productions. The uppermost strata consist of beds of limestone, in some places 800 feet thick, and full of shells. Beneath these beds lie a bed of slaty sandy limestone, and a blue marl, containing also immense quantities of shells still lower. These again rest upon a white laminated marl; and beneath this we have a blue clay containing gypsum, sulphate of strontian, and sulphur, most of them often beautifully crystallized. The great limestone formation occurs in the centre of the island, on the summit of the hill called Castra Giovanni, 3000 feet above the level of the sea. All the beds I have enumerated, except the undermost, abound in marine shells referrible to species still found in the Mediterranean. The inference is undeniable, that Sicily has been elevated at least 3000 feet above the level of that sea, and that nearly, if not more than, 1000 feet of solid strata have been formed belonging to that island since the present species of mollusca began to exist in the ocean." While these beds were deposited at the bottom, there appears to have been considerable volcanic activity in the same regions; for layers of hard compact lava, and that mixture of ashes and limestone called tuffa and peperino by the Italians, are interposed between the limestone and the clay beds. After the whole series of rock had been consolidated, it would seem that the mass must have been violently rent asunder; for there are cracks that traverse all the beds, and these are filled with hard lavas in the manner of our trap dykes. There can be no doubt that these strata were deposited gradually; and that long intervals occurred between the volcanic eruptions, is proved by the following remarkable fact—that Mr Lyell found in the neighbourhood of Vizzini, 25 miles in the interior of the island, a bed of common oysters *(ostrea edulis)*, no less than 20 feet in thickness, interposed between two beds of volcanic lava, and peperino. The Val di Noto is separated from the Val Demone and the region of Etna, by the extensive plain of Catania, which is watered by the Simeto, and its tributary streams. On the northern side of this plain, as we approach Etna, there is a low range of hills composed of the inferior clay strata, mentioned as occurring in Val di Noto. This formation can be traced round the base of the mountain, on the east and south—the strata dipping towards the mountain—so that in their prolongation they would underlie the volcano. These beds do not rise to more than 1000 feet above the level of the sea, and are generally much less elevated. In some places they are 300 feet thick, without the slightest admixture of volcanic matter. In the neighbourhood of Catania, however, they are composed of volcanic tuffa, thinly laminated, and form a steep inland cliff from 600 to 800 feet in height. The sea cliffs northward of Catania are of the sub-Etnaian strata, —as are the rocky islets lying out from their coasts, and the Cyclopean islands fabled as having been hurled against Ulysses and his crew. The largest of these islands is 200 yards from the coast of Sicily, about 300 yards in circumference, and 200 feet in height, and is formed of strata of marl resting on a mass of lava in regular basaltic columns. This lava appears to have heaved up the stratified marl clay; for it is contorted in the most extraordinary manner, and is in some places hardened by the action of the heat to which it has been exposed. These islands then have not been formed, as has sometimes been supposed, by a stream of lava from Etna, for the lava of the islands underlies a formation which underlies the volcano. Such is the nature of the soil out of which the stupendous volcano, 90 miles in circumference, and 10,874 feet above the level of the sea, has arisen.

Whether it has been formed by successive eruptions since the elevation of Sicily above the level of the ocean, geologists have not yet been able to decide; but it seems probable that the mountain was partly formed prior to that elevation, and rose at the same time from the surface of the waters. Of the eruptions of this mountain, ten are recorded as having happened prior to the twelfth year of the Christian era; twelve in the next 1500 years; and

twenty-one from that period till the present time. An eruption of the mountain is mentioned by Thucydides, 425 B. C., which he says was the third eruption of lava from the time the Greeks had settled in Sicily. Another eruption is recorded by Diodorus Siculus, as having occurred in the year 396 B. C., which stopped the Carthaginian army on their march from Messina to Syracuse, and obliged them to go round the whole base of the mountain to reach the city of Catania. This stream of lava is still to be seen on the eastern slope of the mountain, extending over a breadth of more than 2 miles, and having a length of 24 miles from the summit of the mountain to its final termination in the sea. In 1669, an earthquake is mentioned as having levelled the town of Nicolsi, situated near the margin of the woody region, about 20 miles from the summit of the mountain, and 10 from Catania. Two gulfs opened at this time, and threw up sand and scoriæ to such an extent, that in the course of three or four months, the double-coned mountain called Monte Rossi, was formed 450 feet high, and 2 miles in circumference. In the plain of Saint Lio, a ssure 6 feet broad and of unknown depth opened, and ran in a somewhat tortuous course, to within a mile of Monte Etna, traversing a length of 10 miles, and emitting a vivid light. The light emitted from this rent appears to indicate that it was filled to a certain elevation with lava, in an incandescent state, and that probably to the height of an orifice not far from Monte Rossi, which opened at the same time, and poured forth a current of burning lava. This stream, after overflowing fourteen towns and villages—some with a population of between three and four thousand inhabitants—at last reached the walls of Catania, which had been purposely erected to protect the city, but the burning flood accumulated till it rose to the top of the rampart which was 60 feet high, and then fell in a fiery cascade and overwhelmed a part of the city. The wall however was not thrown down, and the solid lava may still be seen curling over the top of the rampart like a cascade in the act of falling. The current of lava on this occasion flowed 16 miles, was 600 yards broad, and 40 feet deep.

Volcanoes are found in every quarter of the globe. In America, between the 10th and 15th degrees of north latitude, there are at least twenty-one at present in action. They are principally situated in the provinces of Guatimala and Nicaragua which lie between Mexico and the isthmus of Panama. An eruption of one of the volcanoes called Consiguina, in that region, broke out on the morning of the 20th of January, 1835, about six o'clock. The vapour which rose from its crater, at this hour, is described as having been very beautiful. At eleven o'clock on the same morning, it spread over the whole of the surrounding territory; and at noon the obscurity was black beyond description, and formed a night of 18 hours' duration, during which, tremulous movements of the earth, strange noises, tempests of thunder and lightning, caused by the combustible matter which filled the atmosphere, and an impetuous wind impelling a heavy shower of ashes, rendered that night a period of distress and horror. The morning of the 21st was melancholy, though the light penetrated through the dense vapours, and the sun sometimes showed a pale and saffron-coloured countenance. The 22d resembled the preceding day, and the night was passed rather quietly, till twelve o'clock. There then commenced a hollow growling sound, vehement and alarming, which was instantly followed by some terrific detonations, loud as the roar of the largest artillery; at a quarter past twelve o'clock the earth shook, and indicated another eruption—which was soon confirmed by the ascent of a volume of smoke. At half-past two o'clock there was a sort of twilight which seemed to interrupt a night of thirty hours' duration. A glare of red light occasionally served to render the darkness visible, and so constant and terrific were the explosions, and the thunder and lightning, that the end of all things seemed at hand. The mountain continued to vomit exhalations, until the 5th of February—cattle and flocks perished, but nothing human. The darkness extended over the whole of central America, for several days, and covered not less than 1500 square leagues with lava and ashes, to the height or thickness in some places, of half a yard; in other places a quarter, but in none less than two inches. On the 9th of March, a commission from the government went to examine the district, and at that distance of time could not see the coast, which was not a league distant, on account of the clouds of smoke that still rested on the land. A forest that had survived many changes upon the surface of the earth had disappeared; two islands had been founded in the sea; some sand shoals had been formed, from 500 to 600 yards long. In one of these a large tree was fixed with its branches downward and its roots raised up. The river Chiquits, which ran towards the north-west, was completely choked up; and another river six yards broad, had sprung up in an opposite direction. A Columbian galley experienced the darkness 61 miles from the shore, as well as a shower of dust, which took the crew 48 hours to remove with spades from the deck. The sounds emitted by the mountain were heard about 1000 miles in every direction, and the ashes already mentioned extended many hundred leagues.

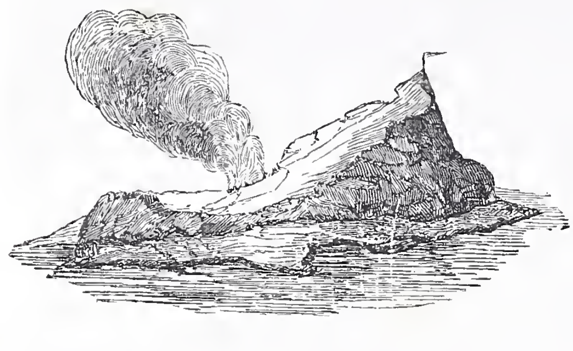
One of the most interesting volcanic eruptions, in a geological point of view, took place in the island of Iceland, in the year 1783. According to Sir George Mackenzie, the lava burst out from the low country, near Shaptar Jokul, at three different points, about 8 or 9 miles from each other, and spread in some plains to the breadth of several miles. The torrent of lava which flowed down the river Shaptar, completely dried it up. The channel of the river was between high rocks, in many places 400 to 600 feet in depth, and near 200 feet in breadth. The lava not only filled up these great defiles to the brink, but overflowed the neighbouring fields to a considerable extent.

These Icelandic lavas, like the ancient lava streams in Auvergne, and other provinces of central France, are stated to have accumulated to a prodigious depth in narrow rocky gorges, but when they came to wide alluvial plains, they spread themselves into broad burning lakes, sometimes from 12 to 15 miles wide, and 100 feet deep. The eruption of Shaptar lasted for nearly 2 years. Twenty villages were destroyed, with about 9000 inhabitants, and an immense multitude of cattle. Such a stream of lava—resembling in its structure and consistency, in a great measure, the trap or whinstone rocks of this country—affords a very convincing argument for their igneous origin, and shows that the large tracts of country covered by them in Scotland, do not exceed in magnitude formations which have taken place in the memory of the living. As might naturally be expected, volcanic eruptions are not confined to the land; some months previous to the eruption of Shaptar Jokul, flames rose from the sea, on the coast of Iceland, which burned for several months, while great quantities of pumice-stone and light slags were washed on shore, and a reef of rocks now indicates the position of the submarine volcano. Another eruption and the formation of another island occurred near the coast, at another part of the island in June, 1830. A submarine volcano forced its way into the atmosphere, near St Michael's, in the Azores, in 1811; it threw up black cinders to the height of 700 or 800 feet above the surface of the water, occasionally ejecting smoke and vapour. But one of the most remarkable, as well as the most recent of these marine eruptions, was the formation of Graham's island off the coast of Sicily, in 1831. On the 28th

Section of Graham's Island.

of June, according to Mr Lyell, about a fortnight before the eruption was visible, Sir Pultney Malcolm, in passing over the spot in his ship, felt the shock of an earthquake, as if the ship had struck upon a sand bank; at the same time shocks were felt on the west coast of Sicily, in a direction southwest to north-east. About the 10th July, the captain of a Sicilian vessel reported, that as he passed near the place, he saw a column of water, like a water-spout, 60 feet high, rising from the sea, and soon afterwards a dense steam in its place, ascending to the height of 1800 feet. The same person on his return from Gergeti found a small island, 12 feet high, with a crater in its centre, ejecting volcanic matter, the sea around being covered with floating cinders and dead fish. The scoriæ were of a chocolate colour, and the water which boiled in the circular basin was of a dingy red. The eruption continued with great violence, to the end of the same month, at which time the island was found 50 to 90 feet high, and three quarters of a mile in circumference. On

the 4th of August, it was again visited by captain Swinburn, and Mr. Hoffman, the Prussian geologist, who found it to be 200 feet high, and three miles in circumference, after which it began gradually to decrease, till, on the 29th of September, its circumference was not more than 700 yards. Toward the close of October, the island was nearly levelled with the surface of the ocean. The island was wholly composed of incoherent ejected volcanic matter, which lay in regular strata, like the cone of Mount Vesuvius. It was reported that, at the commencement of the



Volcanic Eruption on Graham's Island.

following year, captain Swinburn found a depth of 150 feet where the island had formely been. But Mr Lyell observes, that this is quite erroneous; because in the earlier part of this year, he found a shoal and discoloured water there, and towards the end of 1833, a dangerous reef existed of an oval figure, and in the centre was a block of rock of the dimensions of twenty-six fathoms, and from 9 to 11 feet under water; and round this bank were banks of black volcanic stones, and loose sand. At the distance of 60 feet from this central mass the depth increased rapidly. There was a second shoal at the distance of 450 feet west of the great reef, with 15 feet of water over it, also composed of rock surrounded by deep sea. We can scarcely doubt, says Mr Lyell, that the rock in the middle of the larger reef is solid lava which rose up to the principal crater, and that the second shoal marks the site of the submarine eruptions, observed in August, 1831. From the whole of the facts above-mentioned, it appears that a hill, 800 feet or more in height, was formed by a volcanic vent, of which the upper part (only about 200 feet high,) emerged above the waters, so as to form an island.

We have only space to mention another volcano, the phenomena of which is too important to be omitted in a notice of this kind. There are numerous islands in the Pacific Ocean, composed almost entirely of volcanic matter, and in which active volcanoes still exist, which may have been formed, thus—the dome or cone not giving way before the pressure of the water, but gradually accumulating a mass of lava, cinders, and ashes, so that the islands may have become firm, and even of considerable size. Owhyhee, in the Pacific Ocean, is perhaps an example of such an island. The whole mass, estimated as exposing a surface of 4000 square miles is composed of lava, or other volcanic matter, which rises in the peak of Mouna Roa, and Morina Koa, to the height of between 1500 to 1600 feet above the level of the sea. Mr Ellis describes the crater of Kiranea, as situated on a lofty plain bounded by a precipice 15 or 16 miles in circumference, apparently sunk from 200 to 400 feet below its original level. The surface of this plain was uneven, and strewed over with loose stones and volcanic rock, and in the centre of it was the great crater, at a distance of a mile and a half from the place where we were standing. We walked, says Ellis, on the north, where the precipice being less steep, a descent to the plain below seemed practicable; after walking some distance over the sunken plain, which in several places seemed hollow under our feet, we at length came to the edge of the great crater, while a spectacle sublime and even appalling presented itself. Immediately before us yawned an immense gulf, in the form of a crescent, about two miles in length, and nearly a mile in width, and apparently about 800 feet in depth; the bottom of it was covered with lava; and the south-west and northern parts of it were one vast flood of burning matter, in a state of terrific ebullition, rolling to and fro its fiery surges and burning billows. Fifty-one conical islands of varied form and size, containing so many craters, rose within, round the edges, or from the surface of the burning lake; twenty-two constantly emitting columns of grey smoke, and pyramids of brilliant flame; and several of these at the same time vomited from their ignited mouths streams of lava, which rolled in blazing torrents down their indented sides into the boiling mass below.

The number of volcanoes in the Pacific Ocean is greater than in any other quarter of the globe, if we except that part of the Indian Ocean which contains Java, and the neighbouring isles. From Terra del Fuego, they occur in the range of the Andes in South America. In Mexico, this northerly line is met by an east and west line, connecting it with the volcanoes in the West Indies. In California, in North America, there are three volcanoes; America is connected with Asia by the volcanic vents of the Aluetian isles; again, from Kamtschatka, southward, we find volcanoes to the Kurile islands in Japan, the Lechoo islands, Formosa, and the Philippines. The other volcanic regions have been partly described.

With respect to earthquakes, there can be no doubt their origin is to be ascribed to the same cause as that of volcanoes; and that to the agency of both we are to ascribe much of the phenomena we witness, in contemplating the structure of our earth. When we look to the distorted, twisted, up-heaved, and broken state of the strata, with the injected and overlapping masses of matter so analogous to the products of modern volcanoes, as our trap rocks are, we recognise common origin, and witness in these the former volcanic actions of lands now at rest. The effects of modern volcanoes which we have described will show, that even in the historic period there have been rocks produced by volcanic agency, which are almost paramount in magnitude to those of older date; and in thus being enabled to contemplate nature, the student will be more qualified to appreciate the leading doctrine of modern geology, that in all times, and in all places, similar causes have produced like effects; and that to the agencies now in operation, as far as we are able to investigate the phenomena of inorganic matter, we are to ascribe the almighty power which has worked out the physical condition of our world.

We must, however, leave the subject at this point, as it is our intention to treat of earthquakes in our next.

# BIOGRAPHY.

## BENJAMIN FRANKLIN.

Benjamin Franklin, the distinguished American philosopher and statesman, was born in Boston, January 17, 1706. His father—an English nonconformist, who had emigrated to America to enjoy religious freedom—was a tallow-chandler and soap-boiler. Benjamin, the fifteenth of seventeen children, was put to a common grammar school, at the age of eight years; and, from the talents he displayed in learning, his father conceived the notion of educating him for the ministry. But, as he was unable to meet the expense, he took him home, and employed him in cutting wicks, filling moulds, and running errands. The boy was disgusted with this occupation, and was soon after placed with his brother, a printer, to serve an apprenticeship to that trade. His early passion for reading was now in some measure gratified, and he devoted his nights to perusing such books as his limited resources enabled him to obtain. Defoe's Essay on Projects, and Doctor Mather's On doing Good, were among his earliest studies. The style of the Spectator, with which he early became acquainted, delighted him. He gives an account of his exertions to imitate it, in his memoirs of himself. As he had failed entirely in arithmetic while at school, he now borrowed a little treatise, which he mastered without any assistance, and studied navigation. At the age of sixteen, he read Locke on the Understanding, the Port-Royal Logic, and Xenophon's *Memorabilia*. Happening to meet with a work which recommended vegetable diet, he determined to abstain from flesh; and we now find the philosophic printer and newspaper carrier, purchasing books with the little sums he was enabled to save by the frugality of his diet. From Shaftesbury and Collins he imbibed those sceptical notions which he is known to have held during a part of his

life. His brother published a newspaper, which was the second that had as yet appeared in America. Franklin, having secretly written some pieces for it, had the satisfaction to find them well received; but, on its coming to the knowledge of his brother, he was severely lectured for his presumption, and treated with great harshness. One of the political articles in the journal having offended the general court of the colony, the publisher was imprisoned, and forbidden to continue it. To elude this prohibition, young Franklin was made the nominal editor, and his indentures were ostensibly cancelled.

After the release of his brother, he took advantage of this act to assert his freedom, and thus escape from the ill-treatment which he suffered. His father's displeasure, his brother's enmity, and the odium to which his sceptical notions subjected him, left him no alternative but a retreat to some other city. He therefore secretly embarked aboard a small vessel bound to New York, without means or recommendations; and, not finding employment there, he set out for Philadelphia, where he arrived on foot, with his pockets stuffed with shirts and stockings, a roll of bread under his arm, and one dollar in his purse. "Who would have dreamed," says Brissot de Warville, "that this poor wanderer would become one of the legislators of America, the ornament of the New World, the pride of modern philosophy?" Here he obtained employment as a compositor, and, having attracted the notice of Sir William Keith, the governor of Pennsylvania, was induced by his promises to go to England, for the purpose of purchasing types, to establish himself in business.

On arriving in London (1725), he found that the letters which had been delivered him, had no reference to him or his affairs; and he was once more in a strange place, without credit or acquaintance, and with little means. But he soon succeeded in getting business, and, although at one time guilty of some excesses, he afterwards became a model of industry and temperance, and even reformed his brother printers by his example and exhortation. While in London, he continued to devote his leisure hours to study, and wrote a small pamphlet himself, on Liberty and Necessity, Pleasure and Pain. After a residence of eighteen months in London, he returned to Philadelphia, in his twenty-first year, in the capacity of clerk to a dry-goods shop; but he soon returned to his trade, and in a short time formed an establishment in connexion with a person who supplied the necessary capital. They printed a newspaper, which was managed with much ability, and acquired Franklin much reputation.

It is impossible for us to trace all the steps of his progress to distinction. His industry, frugality, activity, intelligence; his plans for improving the condition of the province, for introducing better systems of education; his municipal services, made him an object of attention to the whole community. His advice was asked by the governor and council on all important occasions, and he was elected a member of the provincial assembly. He had begun to print his Poor Richard's Almanac in 1732; and the aphorisms which he prefixed to that for 1757, are well known. At the age of twenty-seven, he undertook to learn French, Italian, and Spanish, and, after having made some progress in those languages, he applied himself to the Latin. He was the founder of the university of Pennsylvania, and of the American philosophical society, and one of the chief promoters of the Pennsylvania hospital. In 1741, he began to print The General Magazine and Historical Chronicle. In 1742, he invented the Franklin stove, for which he refused a patent, on the ground, that such inventions ought to be made at once subservient to the common good of mankind. We might continue this chronological notice of his services, and it would show the remarkable versatility of his mind; but our space forbids us. Being in Boston in 1746, he saw, for the first time, some experiments in electricity, which, though imperfectly performed, were the origin of the most brilliant discoveries which had been made in natural philosophy. We cannot avoid being struck with the immediate practical application he made of his new discovery, in the invention of the lightning-rod.

Franklin had ever shown himself a zealous advocate for the rights of the colonies; and, it having been determined to hold a general congress at Albany, to arrange a common plan of defence, he was named a deputy. On his route, he projected a scheme of union, embracing the regulation of all the great political interests of the colonies and the mother country. The *Albany Plan*, as it was called, after it was adopted by the congress, proposed a general government for the provinces, to be administered by a president appointed by the crown, and a grand council, chosen by the provincial assemblies: the council was to lay taxes for all the common exigencies. The plan, though unanimously sanctioned by the congress, was rejected by the board of trade, as savouring too much of the democratic, and by the assemblies, as having too much of prerogative in it. In 1751, he was appointed deputy-postmaster-general, and, in this capacity, advanced large sums of his own money to general Braddock, the result of whose expedition he foresaw, and in regard to which he made some fruitless suggestions to that general. After the defeat of Braddock, he introduced a bill for establishing a volunteer militia; and, having received a commission as a commander, he raised a corps of 560 men, and went through a laborious campaign. On his return, he was chosen colonel by the officers of a regiment. Pennsylvania was then a proprietary government, and the proprietaries claimed to be exonerated from taxes. In consequence of the disputes to which this claim gave rise, colonel Franklin was sent out (in 1757) to the mother country, by the provincial assembly, as the agent of the province. To aid the cause of his constituents, he published (in 1759) a considerable work, entitled the Historical Review, which was completely successful. His reputation was now such, both at home and abroad, that he was appointed agent of the provinces of Massachusetts, Maryland, and Georgia. Oxford, and the Scotch universities, conferred on him the degree of doctor of laws, and the royal society elected him a fellow. During his residence in England, doctor Franklin formed personal connexions with the most distinguished men of the country, and of the continent; his correspondence with whom displays a striking union of a cultivated mind, with a native and lively imagination. In 1762, he returned to America; but, new difficulties arising between the province and the proprietaries, the assembly determined to petition for the establishment of a regal government, and Franklin was again appointed agent, in 1764.

But the American revolution was now commencing, and he appeared in England no longer as a colonial agent, but as the representative of America. He arrived in London in 1764, about thirty-nine years after his first landing in England as a destitute and deluded mechanic. The project of taxing the colonies had been already announced. He carried with him a remonstrance of the provincial assembly of Pennsylvania against it, which he presented to Mr Grenville before the passing of the stamp-act. He opposed the adoption of that measure, and, from its passage (1765) to its repeal (1766), was indefatigable in his exertions to prove the unconstitutionality and impolicy of the act. When the repeal was about to be attempted, it was concerted by his friends that he should be examined on the whole question before the house of commons. This memorable examination took place February 3, 1766. The firmness, precision, readiness, and epigrammatic simplicity of manner, with which he replied to the interrogatories, mostly put by his friends, were so striking—the information he communicated was so varied, comprehensive, and luminous, on all points of commerce, finance, policy, and government, that the effect was irresistible; the repeal was inevitable. On the passing of the revenue acts of 1767, he became still more bold and vehement in his expostulations, and openly predicted in England, that the inevitable result of those and the other similar measures of the ministry, would be a general resistance by the colonies, and a separation from the mother country. But he never deviated from his original plan, to make every effort to enlighten the public opinion in England, to arrest the ministry in their infatuation, and to inculcate moderation and patience, as well as constancy and unanimity, on America. He endeavoured, at the same time, to stand well with the British government, aware that this was necessary to enable him to serve his country effectually; while he never ceased to proclaim the rights, justify the proceedings, and animate the courage of his countrymen. He was not ignorant, to use his own words, "that this course would render him suspected in England of being too much an American, and in America of being too much of an Englishman." His transmission of the celebrated letters of Hutchinson and Oliver (1772), which had been placed in his hands, is not the least memorable of his acts at this opening period of the revolution. He immediately avowed his own share in the transaction, although he never divulged the names of the persons from whom he had received them. The indignant petition of the assembly of Massa-

chusetts, in consequence of these letters, was presented by him to the ministry; and he was immediately made the object of the most virulent abuse, and held up to the hatred and ridicule of the British nation. He met the conflict with no less spirit than wit, as is particularly exemplified in his two satirical pieces, the Prussian Edict, and the Rules for reducing a great Empire to a small one. At the discussion of the petition before the privy council, Franklin was present. Wedderburn, (afterwards lord Loughborough,) the solicitor-general, assailed him with the most coarse invective, styling the venerable philosopher, and the official representative of four of the American provinces, a "thief and a murderer," who had "forfeited all the respect of society and of men." The ministry now dismissed him from his place of deputy-postmaster-general, and a chancery suit was instituted in relation to the letters, for the purpose of preventing him from attempting his own vindication. Attempts were made, as the difficulties increased, to corrupt the man whom it had been found impossible to intimidate; "any reward, unlimited recompense, honours, and recompense, beyond his expectations," were promised him; but he was as inaccessible to corruption as to threats. It was at this period that he presented the petition of the first American congress; and he attended, behind the bar (Feb. 1, 1775), in the house of lords, when Chatham proposed his plan of a reconciliation. In the course of the debate, that great man characterized him as "one whom all Europe held in high estimation for his knowledge and wisdom; who was an honour, not to the English nation only, but to human nature."

Having received an intimation, that the ministers were preparing to arrest him, as guilty of fomenting a rebellion in the colonies, he embarked for America, and was immediately elected member of the congress. As a member of the committee of safety, and of that of foreign correspondence, he performed the most fatiguing services, and exerted all his influence in favour of the declaration of independence. In 1776, he was sent to France as commissioner plenipotentiary, to obtain supplies from that court. He was net, at first, publicly received in his official capacity, but he succeeded in gaining the confidence of the count de Vergennes; and, soon after the reception of the news of the surrender of Burgoyne, he had the happiness of concluding the first treaty of the new states with a foreign power, Feb. 6, 1778. For the particulars of this mission, we must refer to his correspondence. He endeavoured to establish the credit of America throughout Europe, by his essay, entitled Comparison of Great Britain and America as to Credit, in 1777. No sooner were the capture of Burgoyne and the treaty with France known in England, than the ministry began to talk of a reconciliation. Emissaries were employed to sound Franklin as to the terms on which this *reconciliation of the colonies* could be effected; but he rejected every idea of treating except on the basis of independence. "The Americans," he said, "were neither to be *dragooned* nor *bamboozled* out of their liberty." The next act of the British ministry was to endeavour to separate America from France, and to excite a jealousy between the two countries; but all these wiles were defeated by the firmness and prudence of the American minister.

After the conclusion of the treaty with France, Franklin had been appointed minister plenipotentiary to that court (1778), and was subsequently named one of the commissioners for negotiating the peace with the mother country. At the close of the negotiations (November, 1782), he requested to be recalled, after fifty years spent in the service of his country, but could not obtain permission to return till 1785. During this interval he negotiated two treaties, one with Sweden, and one with Prussia. The general enthusiasm with which he was received in France is well known. His venerable age, his simplicity of manners, his scientific reputation, the ease, gaiety, and richness of his conversation,—all contributed to render him an object of admiration to courtiers, fashionable ladies, and *savants*. He regularly attended the meetings of the academy of sciences, and was appointed one of the committee which exposed Mesmer's "imposture of animal magnetism." At a meeting of the academy, he met Voltaire, then in Paris, on his triumphal visit. The patriarch of letters and the patriarch of liberty met before a crowded hall, and embraced. On his return to his native country, before he was permitted to retire to the bosom of his family, he filled the office of president of Pennsylvania, and served as a delegate in the federal convention, in 1787, and approved the constitution then formed. He died April 17, 1790.

# HISTORY.

## CHAPTER V.

### ROME.

The early history of European civilization has its scene of action on the coasts of the Mediterranean. On the shores of this great inland basin, the first efforts in war and commerce—the first efforts in science and art—the results of which are still employing the minds and influencing the destinies of every quarter of the globe, were made. At the dawn of history we can descry a thin belt of comparative civilization encircling the sea-coast. As the light grows steadier and broader, we see this belt deepening and extending inward on all sides; but more especially in a northerly direction, into the continent of Europe. And from Europe again, we see it casting out wide arms on both sides, which, groping over Hindostan and America, grapple at the antipodes, and enfold the world within their circling embrace. But we are anticipating.

That portion of the earth, to which we shall confine our attention in this chapter, in a great measure is marked out by very definite natural boundaries. Cast the eye over the map, and at the widest part of the Mediterranean sea, will be remarked a boot-formed projection of land, shooting out from the continent of Europe. This is Italy.

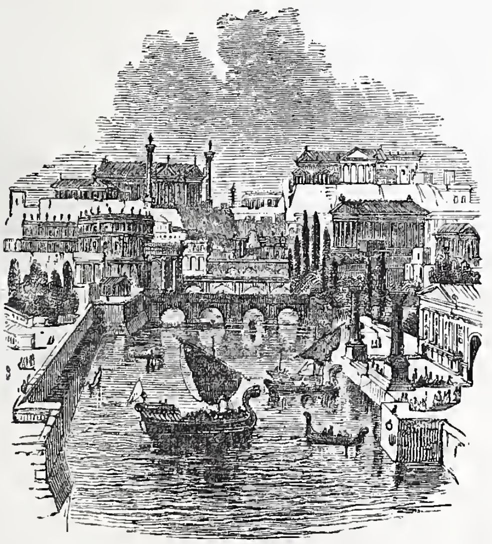
At the northern extremity of this long and comparatively narrow stripe of land—for, extending about eight degrees of latitude in length, it nowhere exceeds one and a half of those degrees of longitude which we find midway between the pole and the equator, in breadth—the Alps stretch in a semicircle from sea to sea, forming a marked natural line of demarcation between it and the north of Europe. It is separated from Gaul and Spain on the west, by what was of old termed the Tyrrhene, or Nether Sea—that section of the Mediterranean which terminates in the recess of the gulf of Genoa. It is separated from Illyria and Greece, on the east, by what was of old termed the Iapygean sea—that portion of the Mediterranean which terminates in the gulf of Adria. To the south, it is separated by the Mediterranean, from the northern coasts of Africa.

The features of this land, so portioned out from the rest of the world by precise boundaries—at least in so far as our present object is concerned—are very strangely marked. From the western extremity of the Alps, the chain of the Appenines sweeps in a curve nearly along the centre of Italy, till it approaches the southern extremity. There it divides into two branches, each terminating on the sea-coast; the one at what may be termed the heel of the boot—the other at its toe, upon the strait which separates Italy from Sicily. Everywhere in Italy, on both sides of this central ridge, we find predominating traces of volcanic agency. In the tributary vallies which open into the great plain of the Po, they are frequent and unquestionable. In the section of a circle—of which the sea forms the chord, and the mountain ranges the arc—extending from the bottom of the gulf of Genoa to the cape Circeii, the whole soil is volcanic; men move and build and toil upon the surface of one great dormant, rather than extinct volcano. In the smaller circular segment, of which Naples may be regarded as the centre, we find the volcanic principle in intense activity; and know from a chain of connected record, that it has continued thus since a period very little posterior to the Christian era. Italy stretches from the 38° of north latitude to the 46°; it lies entirely, therefore, within the warmer section of the temperate zone. Two circumstances conspire to modify its climate. The height of the central mountain range, and the numerous narrow valleys intersecting it, produce cold, and disseminate heat and cold, in violent currents and gusts of wind. The volcanic nature of the subsoil generates intermitting eruptions of hot and fœtid vapour. The obstructions opposed by the volcanic rocks, which have been thrown up from time to time, to the watercourses, generate multitudes of small lakes and marshes, keeping the atmosphere more laden with moisture than it would otherwise be. The consequence of these facts in the natural history of Italy, is a more variable weather, than from its position on the globe, we should have

been led to anticipate. The consequence too is a great variety in the fertility of the land. Where the volcanic agency is active, and even where it is in a dormant state, we have frequent tracts of desert thankless soil, aecrusted with salts, and tainted by vapours fatal to germination. Where the volcanic agency is extinct, and even in spaces scattered through the regions where it still predominates, the debris of the volcanic rocks yield a fertile soil; and the marshy spots to which we have already alluded, beneath the conjoined influence of a powerful sun from above, and heat from the internal fire which smoulders below, presents us, in despite of its variable climate, with an almost tropical rankness and redundancy of vegetation.

Our business with the land which we have thus, in its general aspect, endeavoured to render familiar to the imagination of the reader, is to trace the fortunes of a state, which, occupying at first a scarcely perceptible space on the surface of its map, came in due course of time, first to rule over the whole of this Italy as a sovereign, and then to identify the whole of Italy with itself.

Cast your eyes again upon the map—upon that portion of Italy, to which we have already adverted, as limited by the sea as its base line, and the arc of hills sweeping from the bottom of the gulf of Genoa, to the cape of Circeii. About the middle point of this circumferential line of hills, are the sources of a stream, which flowing in a south-west direction, and forming the central drain of a wide valley, reaches the sea, not far from the southern extremity of this section of Italy. This is the Tiber. The greater part of the course of this river, is slanting at an acute angle to the seacoast. As it approaches, however, within some sixteen or twenty miles of the sea, it forms a curve, and the rest of its course is almost perpendicular to the sea. Nearly at this curve, the Tiber receives the waters of the Anio, a stream which—with a somewhat shorter course, and flowing from the south-east, as the Tiber from the north-east—forms, in like manner the drain of a considerable range of country. Not far below the junction of these streams—the names of which are familiar to all as household words—on the left bank of the Tiber, stands the city of Rome. This is the cradle of the infant



ANCIENT ROME.

state of which we speak—this was the capital at one time of the known civilized world—this has been the central place of worship of the Christian world. It was the natal soil of these conceptions of law, which, embodied into different forms of government, ruled the opinion—and through the instrumentality of opinion, rule three-fourths of the inhabitants of the globe at the present day. It is the root striking deep, and widely-ramified, from which sprung up our European civilization—it is the natural starting-point of our attempt to trace the growth of that civilization.

In entering upon this task, it will be advantageous to distinguish the historical plain over which we are required to traverse, into five divisions; which we find marked out in the map of time by characteristic features, and which the mind easily recognises, although the lines of demarcation should be dim in the written pages of history. These divisions are the following:—

1st. The mythological era of Rome's history.

2d. Infant Rome—the development of the constitution of Rome within the city walls, down to the election of the first Plebeian consul, and the burning of the city by the Gauls—events which happened, the latter in the 363d, and the former in the 387th year of the city.

3d. The conquest of Italy—the further development of the constitution during that period, in which Rome was bringing the whole of Italy under her sway. This period terminates about the commencement of the first Punic war—*i. e.* about the year of the city 490.

4th. The amalgamation of Italy and Rome—the series of transactions foreign and domestic which terminated, shortly after the close of the Jugurthine war, with admitting all the Italians to the right of citizenship—that is in the year of the city 665.

5th. The fifth period renews the struggle of factions, under the fully developed constitution, terminated by the usurpation of Cæsar, in the 703d year of the city.

Although we thus mark out our history into five periods, it is not to be understood that such distinctions exist in reality. The current of events is uninterrupted. The events of one moment of time are interlaced by a thousand minute fibres with each other. The gradual changes in the face of society are worked out by incessant and minute modifications. Viewed with regard to the date at which one period ceases and another begins, there is no difference between them. Viewed, however, with regard to the general character of the long tract of years assigned to each period, a marked difference is perceptible. These periods are assumed, and arbitrarily marked out as an aid to memory. The history of the Roman republic is one great event—we might say the history of the human race is one great event. This much to prevent misconception.

MODERN ROME.

I. The first period we intimated would embrace the mythological history of Rome. Some authors have set themselves to separate between the different ingredients of the legendary fictions possessed by every nation, and assign one portion to history and another to imagination. They have here undertaken a task impossible of accomplishment. Truth is a statement or representation corresponding with reality; fiction is a statement or representation which has no counterpart in the world of existences. How can we ascertain of any one iota of traditionary history that it ever had a counterpart in reality? The realities

which were its counterparts have passed away and for ever, leaving no authenticated memorial behind them. Of some legends we may say, that their palpable contradiction to the laws of nature stamps them as false ; but of what legends can we say that they not merely may be, but are true ? The test adopted by the class of writers we are referring to, has been to assign to the region of fiction all legends of an imaginative stamp—to the region of history all that are prosaic in their character. This is no trustworthy test. There are dull lies as well as interesting ones; and there are ascertained facts in history, wilder than the most daring imagination ever dreamed of in romance. This sifting process is unavailing. Legendary tradition is insensibly distinct from history. To blend the two in one mass is to construct an idol, partly of brass and iron, partly of clay.

Still the legends of a nation form part of its history, and an important part. Their peculiar characters are illustrative of its character. As the heart feels, the imagination conceives. The heroes and demigods of a nation are the incarnation of what the men of that nation most admire—of the qualities in the possession of which they most pride themselves. Nay more, the constant habit of having these heroes and their exploits held up to his infant admiration, tends to form the character of the boy and thence of the man. The legendary lore of any people is first stamped with the moral character most predominant amongst that people ; but when once it has attained a precise and definite form, it re-acts upon them with even more force than they acted upon it. It soothes their vanity—it corroborates their prejudices—it makes them ten times more intensely what it found them. The legends of a nation are that nation's passions reflected of gigantic stature—like the spectre of the Brocken on the cloud of imagination; and men, pleased with this colossal image of themselves, strive like the frog in the fable to inflate themselves to its size. It is not because it contains hints of times which have died and left no record, that national mythology is an important branch of a nation's history; it is because it is a living and enduring reality in the national imagination—the object of its idolatrous worship—the strengthener, when not the origin, of its peculiarities—that it is indispensable we should know it, in order to know the nation itself aright.

It is no easy matter to learn the details of pure Roman mythological and legendary fable. The Roman authors who have come down to us are all more or less imbued with Grecian as well as with Roman poetry. What they give us is a compound of these two original elements. Thus we find the old legend of Rhea Sylvia, strangely mixed up with the Grecian legend of Troy and its fugitives; and the local deity Mars confounded with the Ἄρης of the Greeks. That there was an indigenous system of polytheistic superstition in the valleys of the Anio and Tiber is clear enough ; but of what has been transmitted to us by Roman authors, how much flows from this source, how much has been borrowed from the Greeks, it is hard to say.

The local peculiarities of the territory may aid us in the conjecture. The native seat of Rome is on the seven hills. Some miles below the junction of the Anio and Tiber, was a low marshy plain, on the left or southern bank of the united waters, round which the stream made a bold sweep. Landward. the rising grounds toward Mount Algidus enclosed this marsh as it were on three sides of a circle—tongues of high land projecting from the circumference into the marsh at five places. In the centre stood an isolated, steep, and craggy eminence, afterwards designated the Capitoline rock or hill; and between this and Mount Aventine—the most westerly of the prolongations of the uplands mentioned—stands another isolated mount designated in after times the Palatine. From these five tongues of elevated land the country continued to ascend to the south by a scarcely perceptible rise, till it reached the base of that extinct crater, which forms the bed of the Alban lake; behind which, rather to the eastward, towers Mount Algidus. Eastward, there was a considerable tract of level land lying on both sides of the Anio, and extending to the left bank of the Tiber. At the eastern extremity of this plain ascends the bold crags, within which Tivoli is embosomed. North of the Tiber was a rocky land abounding with small lakes, the beds of extinct volcanoes—and channelled and fretted, like the wrinkles on an old man's face, by innumerable streams. Toward the seacoast, that is westward of the city, the elevation of the soil sunk rapidly. On a line with the city, and further inland, the rocks are all of volcanic origin—chiefly a kind of tuffa ; or the same sandy barren tracts alternate with salt marshes. Rank and deleterious vegetation clothes the one ; the other is covered with forests of evergreen, oak, and a kind of cork-tree. The same deep forest growth hid the base and ascent of Mount Algidus. Inland, marsh and forest alternated. Amid this rude but not sterile country, several states had sprung up to power before the foundations of Rome were laid. The united towns of Etruria pressed upon it from the north ; the Ascans under the names of Volscians, Samnites, Hernici, and the like, from the east and south-east. The kindred Latins occupied a narrower territory to the south-west. It would almost seem as if the ruder Romans had borrowed some items of the more developed mythology of these surrounding states. The creeds of all were framed by men of kindred characters under the same skyey influences, amid rocks and groves of a similar character. They were the same at bottom with the Roman, but more elaborately worked up. This circumstance seems to have given a fragmentary and mechanical character to the Roman mythology from the beginning. The attributes of their deities were vague and fluctuating; and sometimes the same powers and functions were attributed to more than one. To this we should incline to attribute the great readiness of the Romans to receive into their veneration the gods of every nation they came in contact with—a circumstance which ultimately extended their hierarchy of gods, till it broke down with the weight of its own numbers, but at first materially facilitated their progress as conquerors. The early names of the indigenous Roman gods have perished; but their characteristics have survived, and they have a strong look of their natal soil. One of the most prominent was Fever—a natural goddess in a land of marshes and miasma. Another was Terror—that strange panic-striking being which alternately stupified the Roman and the enemies' ranks. All have felt the influence of half-developed bad health in inducing seemingly causeless despondency; and we can understand how men, unacquainted with the cause of their flagging spirits, and equally unable to account for the return of their buoyant elasticity, should refer both to unseen spiritual influence. Another deity of Rome was the power which breathed stability—the power of enduring resistance to the assaults of enemies—into the breasts of men. Another was the god of good counsel. To all these powers we find altars erected in early Rome. Sometimes the name of the deity was borrowed from a neighbouring state—sometimes a ready-made god, possessing the attribute wanted along with others, was thus introduced. But the original suggesters of the Roman gods were the wishes and the fears of the hearts of men—the ever-blended consciousness of weakness with yearning after strength. But the forms in which imagination clothed these elementary emotions are but the mirrored objects of surrounding nature. The power which burned up the vitals and withered the healthy juices, emerged from the blue mists of the marsh and waste, lighted on its way by meteors. The awe-inspiring god was heard in the melancholy inscrutable and inarticulate moan of midnight forests. The god who enabled men to stand firm in the hour of danger was arrayed in warrior's garb.

It is, however, when we descend to the legends of heroes, and the traditions of the early priesthood, that we recognise at once the vigour and the rudeness of the age in which they originated. Rapacity—an overwhelming desire to accumulate—craft in devising, and courage in extending plans of spoil—are the most admired characteristics of the early heroes. Continence is a virtue, not from any of the refinements which belong to a more cultivated age, but because it is conducive to strength and martial vigour. It was at the altar alone that there was safety for man, beyond what his own skill and vigour could ensure him ; and even here it was only precarious. A curious illustration of this occurs in a rude bas-relief turned up some years ago at Nemi, a little south of the Alban lake, which gives and receives light from allusions in some classic writers. In the centre stands a clumsy and ferocious but athletic figure, armed with a sword. An equally truculent personage, in a recumbent attitude, is expiring from a deep sword-wound in his side. Some wild-looking females in dresses of skin, are heaping blandishments, congratulation, and adoration, on the conqueror. By means of hints in the classical writers the story of this sculpture may be read. One of the oldest recorded seats of local superstition was at Nemi; and there we are informed that the officiating priest, termed *rex*, held his office in virtue of having killed his predecessor—and held it only so long as he could ward off the assaults of any who were courageous and ambitious enough to aspire to

his place. This is perhaps the wildest tradition of the reckless pride of ferocious strength, that the annals of mankind preserve. But in the original form of the Salic dances, and their ruder songs, we have ebullitions of maniac ferocity, scarcely softened from the Bacchanal congratulations which the weird-like priestesses are heaping on the triumphant murderer.

The first moral admixture in this lawlessness of will and imagination—the first softening effort of control of the passions we can recognise, is the injunction of continence as a strengthener of the warrior's arm. The next was the practice of justice and kindness to the fellow-citizen. Hatred and contempt of the foreigner were allowed, and even encouraged as a sort of lightning conductor, to lead off the desolating influence from the inmates of the same city. These narrow virtues—like those of all rude nations—were the cold result of calculating selfishness. But the habits of self-restraint which they prompted, in course of time, lent greater grace and nobility to the character notwithstanding. To save a Roman citizen in battle was to earn the proudest of the wreaths bestowed on victors. From the earliest periods of the recorded history of Rome—and even tradition breathes the same feeling—we find women occupying a happier position than in any other state of antiquity. We can recognise this in the legend of the Sabine women, who although rudely torn from their friends were soon taught to love their ravishers better.

These were the elements of the popular mythology and tradition of Rome—for the secret knowledge of the pontiffs and augurs was a very different thing. This superstition was of indigenous growth, and was fashioned into a kind of consistency and coherency by the lapse of time, not by deliberate forethought. The elementary powers of nature wielded, according to it, the sovereign sway. The advancement of the nation in a rude morality communicated in time something of a moral character to their duties. The ferocity of the ebullitions of savage enthusiasm became regulated rather than softened; for, down to the close of the Roman republic, the *virtus* which the Romans admired was more akin to valour than to what we now designate virtue. Reaching back into the past in order to confer at least a past eternity upon the deities of their imagination, the old traditions of volcanic agency were blended with other elements of awe; and hence the pit of Acheron, the fire-breathing Cacus, and other inflammable apparitions. This mass of superstition filled up the popular imagination of Rome, and domineered over it for centuries,—the growth, in the first instance, of Roman character, it became mainly instrumental in keeping the Romans what it found them. To appreciate the Roman aright—to understand him—we must remember that his belief was ever present and powerful in him; that whatever physical objects might greet his eye, these were ever present, "Lords of the visionary eye, whose lid falls not and cannot fall." Dreams we may call them—fantastical, unsubstantial they are—but they regulated the actions of a powerful people for a thousand years; and if they be dreams, they have outlived their dreamers.

## DOMESTIC MEDICINE.

### CHAPTER II.

ON THE ADAPTATION OF THE EXTERNAL WORLD TO THE PHYSICAL WELL-BEING OF MAN, AND ON THE MORAL CAUSES OF DISEASE.

The Scriptures tell us, and geology proves to us, that man has been only a few thousand years a tenant of this world—a drop of time, compared to the ocean of ages that intervened between the creation of the first simple vegetable and the first simple animal on the earth's surface, and the appearance of the human race, surrounded by the palm, the cedar, and the sycamore, the elephant, the camel, and the horse. There is abundant evidence to prove, that during the whole of this vast period, the world was undergoing a silent and gradual preparation for the reception of man. It was made subject to the universal law of gravitation, without which it could neither have been retained in its sphere round the sun, nor would water or any moveable body have remained on its surface. By gravitation, water falls to the earth, seeks its lowest level, and forms itself into rivers, lakes, and seas. The globe was raised up in various parts into mountains. At first sight one is apt to think that the sole use of these is to preserve the boundary between the dry land and the sea, but, on a closer investigation, he will discover that they have other uses of great importance. In a country destitute of high mountains, rains suddenly swell the rivers to enormous torrents, bursting their banks, expanding into internal seas, inundating cities and villages, and involving the labours of man in wide-spread ruin; whereas, lofty mountains, covered with their eternal snows, not only serve as the grand storehouses of nature for retaining the superabundant rain, giving out, by the summer heats, a gradual and inexhaustible supply to the otherwise dried up river channels; but they also contribute in a great degree to temper the climate, by cooling down the air with which they come in contact, and which, by its increased density, descends to the plains below, producing those cool and refreshing breezes which are unknown in a flat country, where extreme vicissitudes of heat and cold are apt to prevail. The globe was also provided with an atmosphere and an ocean of peculiar composition and qualities. The ocean was destined to be the receptacle for all impurities soluble in water, which might prove noxious to animal life. The atmosphere was intended as a receptacle for the vapours and all noxious exhalations which arose from the earth's surface; it was also to serve as the medium for purifying the waters of the earth and the sea, and redistributing them over the dry land in genial showers of rain, which are absolutely necessary for the continuance of vegetable and animal life. These showers produce springs, springs brooks, brooks rivers, the rivers flow into the ocean, to be again evaporated into the atmosphere in the form of clouds, to descend in showers; and thus to flow in a beautiful circle of endless harmony. Even the very rocks of which the world was composed evinced supreme wisdom on the part of the Creator. The nature of the huge unwieldy masses of rock, whose decomposition by water forms the soil, would in our opinion be a matter of little importance; whereas, had they not contained the identical chemical ingredients which they do contain—had they not been of the very *hardness* which we find them, it would have been impossible, according to the present constitution of vegetable substances, that the earth could have been covered with trees and herbage—they could not otherwise have had the gradual supply of nutriment necessary for their health and growth.

The globe being thus provided with air and water—with light, heat, day and night, change of seasons, and with rocks capable of becoming the food of plants, "God said, Let the earth bring forth grass," and the first vegetable sprung into existence, and the barren rocks became clothed with verdure.

We have every reason to suppose, from observing in nature a scale of being, rising by insensible gradations from the simplest vegetable to the most complex form of animal life, that plants of the simplest structure would be first created. By degrees, vegetables of more complex structure would appear; and, as we ascend in the scale, we find animal life coming into existence, but as yet in so simple a form, that it is almost impossible to distinguish the animal from the vegetable. We thus see the three kingdoms of nature—mineral, vegetable, and animal—running into one another by almost imperceptible steps, the line of demarcation between them being nearly impossible to draw.

Plants must have been created before animals; for, to enable animal life to exist, vegetable life must have been in existence, to serve as a connecting link between the inert or dead matter of which the earth was composed, and the living fabric of animals. Vegetables throw out their roots into the soil, from which they absorb or suck up part of their nourishment. They expand their leaves into the air, and absorb another part of their nourishment from the atmosphere. Animals are not formed to derive their nourishment from the soil. Should they endeavour to do so, the attempt would soon be fatal. Vegetables were therefore necessary first, and that of the simplest sort, to be the food of

the simplest forms of animals. All animals must thus, in the first instance, have been herbivorous, or adapted for living solely upon vegetables. But if no other provision had been made, these herbivorous animals would have increased to such a degree, that the whole of the herbage of the earth would not have been sufficient for their maintenance. They would have died of starvation, and the different species would have become extinct. Carnivorous animals were, therefore, necessary to keep the animal kingdom from outgrowing the means of its subsistence, before the world was occupied by man.

The globe, being now covered with vegetation, and inhabited by numerous species of animals, might seem to our short-sighted comprehension to be properly prepared for the abode of man. But had he been created at this period, how limited would have been his means of progressive improvement! Coal, that valuable mineral, to whose power the wonders of steam are so much indebted, would not have been in existence. An insurmountable obstacle would thus have been presented to the improvement of commerce, manufactures, and a thousand useful arts. Limestone and several other minerals would have also been wanting. A wise and benevolent Providence, however, decreed otherwise; and geology tells us, that five races of plants and four races of animals were successively created, that each lived for several ages, and that, by the physical revolutions of the globe, they were swept away, before the earth was considered fit for the permanent abode of the human race.

By this brief sketch, we see that the world was gradually prepared for the abode of man; and were we to study the physical constitution of man and of external things, we would see, at every step, how beautifully the one is adapted to the other. Had he not had air to breathe of the exact composition and density of our atmosphere—had he not had water to drink of that fluidity and quality which it possesses—had not the world been of the size and shape that it is—been placed at that distance from the sun at which it is placed—had not man been created neither herbivorous nor carnivorous, but omnivorous, so as to enable him to live on vegetables or the flesh of animals according to circumstances; in short, had not man been constituted exactly as he is, and the external world been constituted exactly as it is, his life would have been contrary to the laws of nature, and we cannot conceive how he could have existed. The various relations of man to the external world, and their beautiful adaptation to one another, would fill volumes; and how strangely constituted a mind must he have, or how ignorant must he be, who can conceive it possible that such an arrangement could have taken place without infinite design, power, and wisdom!

Every member of the animal and vegetable kingdoms was placed originally in circumstances favourable for accomplishing a certain period of endurance, and, if no accident occurred, for accomplishing this period in good health, at the end of which its life terminated. But if an animal or vegetable happened to be placed in unnatural circumstances, such as to be deprived of a sufficiency of nutriment, or exposed to any noxious influence, that animal or vegetable fell a prey to disease, and was thus prevented from accomplishing its natural period of healthful endurance. Vegetables and animals have, therefore, their diseases, more or less severe according to the cause. The finer the organization of the living being, the more liable it is to disease, and its diseases are the more complex. Man is, therefore, more liable to disease than the inferior animals, the inferior animals than plants; the diseases of the human being are more complex than those of plants or animals, in proportion as his organization is infinitely more complex than theirs.

Man was placed in this world subject to the same physical laws as the inferior animals; but, in addition, the impress of his Creator was stamped upon his mind—he was created a rational being, he was endowed with intellectual capacity, he was to be the subject of future rewards and punishments; and he was placed under moral laws. Man's reason tells him, that if he breaks the physical laws, he subjects himself to injury, disease, or death, as the case may be. For example, if he allows himself to fall from a precipice, he either lames or kills himself, being subject to the physical law of gravitation; if he continues to breathe air deprived of oxygen gas, he very soon dies, it being one of the physical laws that a certain supply of oxygen to the lungs is absolutely necessary for the continuance of life; and so on of other physical laws, as we shall afterwards see. Our object in this chapter is to show, that an infringement of the moral laws is also a most powerful cause of disease, tending to shorten the natural period of existence, and is a source of much acute misery to mankind; so that, even in a medical point of view, "virtue is its own reward, and vice is its own punishment."

The rudest tribe of savages, that occupies the lowest place in the scale of moral degradation, and which appears little elevated above the higher classes of the brute creation, has still left within it some perception of right and wrong, has still some moral laws by which the members of its community are governed, to the infringement of which penalties more or less severe are attached; thus verifying the words of the apostle, that "the Gentiles, who have not the law, do, by nature, the things contained in the law; these, having not the law, are a law unto themselves; which show the works of the law written in their hearts."

It will be found that the more elevated the moral code of any nation is, and the clearer its perception of right and wrong, the higher is the place it will occupy in the scale of intellectuality; that the whole of the human body, the brain in particular, will be more finely developed—the greater will be the exemption from disease, and the longer will life be prolonged. Whereas, on the other hand, the lower the code of morality, the more deficient in intellect will a nation be; the more deformed, the more diseased, and the shorter-lived will its inhabitants become. It is, therefore, a fatal mistake to affirm, with the Phrenologists, Materialists, *et hoc genus omne*, that the low state of morality and deficiency of intellect in a country, is to be ascribed to the small and misshapen brains of its citizens, to the preponderance of their animal propensities over their moral faculties. The very reverse of this is true; and these pretended philosophers commit the egregious error of mistaking the effect for the cause. It is a fact well known to physicians, that the development of every bodily organ is increased by continued healthful exercise. It is also well known to every student of mental philosophy, that the moral and intellectual faculties of the mind are vastly improved by cultivation; and every breeder of cattle is aware of the law in animal organization, that "like produces like." If, then, it can be proved—which it can be—that a child, born with certain animal propensities, and certain moral and intellectual faculties, can have these moral and intellectual faculties cultivated and developed by education, so as to balance or preponderate over its animal propensities, according to their original relation to one another; that this increase in its faculties will influence the size and form of the brain, and that this child will transmit these acquired physical and mental peculiarities to its progeny: it therefore follows, that the intellectual capacity and physical development of the inhabitants of every nation are in a direct ratio to their intellectual and moral training; in short, to the purity of their moral code, carried through a series of generations. The history of antiquity shows, that the higher a nation rises in the scale of virtue, the higher it rises in its superiority over other nations; the more powerful, both physically and intellectually, does it become, and the various arts and sciences arrive at the greater perfection. But let it sink in that scale, and exactly in the proportion in which it descends does it lose intellect and physical superiority, and the development of the brain more nearly assimilates to that of the savage. The kingdoms of ancient Greece and Rome afford melancholy examples. As long as their moral codes were strictly adhered to and faithfully obeyed—as long as national virtue maintained its superiority—so long did they maintain their sway over the surrounding nations; so long did they improve in all the arts and sciences; giving posterity the most splendid proofs of the strength of the national intellect, in their philosophy,

their poetry, their architecture, and their art of war: their citizens were virtuous, their sons men of genius, their soldiers were brave, and their armies powerful. At length, however, immorality and vice took possession of the land; their rulers became intoxicated with voluptuousness and dissipation, their citizens were dissolute, their soldiers effeminate, and their armies vanished like smoke before the brave barbarians of the north, whose moral discipline was more stringent, and to whom the short-lived and debasing pleasures of wine and other luxuries were unknown. What became of the finely-developed brain and corporeal form, and the high intellectual faculties, of the Grecian and Roman then? And where are they now? Their laxity of moral discipline sank them in the scale of civilization and intellectual development, to a condition little superior to that of the savage.

But diminished intellectual capacity and deficiency of physical power, are by no means the only national and individual evils produced by a laxity of moral discipline; for, wherever there is the greatest moral depravity, there is, of course, the greatest crime; wherever there is the greatest crime, there is the greatest ignoranee; and wherever there is the greatest ignorance, there is the greatest amount of disease, decrepitude, delicate constitutions, premature old age, and earthly misery. What a tremendous reponsibility, then, is there upon every individual head of a family! As he is accountable to his children and his posterity for his character and position in society, so is he infinitely more accountable for the improvement of his moral and intellectual faculties, and for the preservation of his physical constitution from disease. The Scriptures tell us, that the "children are punished for the sins of their fathers, even unto the third and fourth generation;" and there is no doctrine more clearly established by experience and observation than this—that the child inherits in a greater or less degree the physical and mental peculiarities, and even the very diseases of its ancestors. Many of the diseases which are termed *hereditary* are the worst which can afflict the human race; and although physical causes contribute considerably to their *original* production, moral causes operate by far most powerfully, not only in producing them originally, but also in aggravating any predisposing tendency to their occurrence, which may be inherited from our forefathers. Among hereditary diseases may be enumerated, insanity, epilepsy, scrofula, consumption, cancer, gout, asthma, &c.; and were we to trace the history of any of these in the records of medical science, we would find their origin mainly attributed to the operation of moral causes. Dr. Winslow, in his Psychological Journal, alludes frequently to the marked yearly increase in the number of cases of general insanity during the last twenty years. He says they are far more than can be accounted for by the increase of population; and this circumstance he ascribes to the greater prevalence of opium-eating in the community. Opium-eating is the worst species of drunkenness; and that it is increasing to an alarming degree, the account-books of every apotheeary can testify. Dr. Macnish, in his "Anatomy of Drunkenness," says, that though at first it excites pleasurable feelings, its continuance brings on disease upon the constitution, and, "instead of disposing the mind to be happy, acts upon it like the spell of the demon, calling up phantoms of horror and disgust." "Nor," says he, "is this confined to the mind alone; for the body suffers in an equal degree. Emaciation, loss of appetite, sickness, vomiting, and a total disorganization of the digestive functions, as well as of the mental powers, are sure to ensue, and never fail to terminate in death, if the evil habit which brings them on is continued."

We next come to epilepsy. Have moral causes anything to do with the production of this horrible malady, which is so apt to terminate in madness or apoplexy? Listen to Dr. Watson, in his celebrated "Lectures on the Principles and Practice of Physic." In vol. i., p. 627, he says, "There are certain vices, which are justly considered as influential in aggravating, and even in creating, a disposition to epilepsy: debauchery of all kinds; the habitual indulgence in intoxicating liquors; and, above all, the most powerful cause of any, not congenital, is *masturbation*—a vice which it is painful and difficult even to allude to in this manner, and still more difficult to make the subject of inquiry with a patient. But there is too much reason to be certain, that *many* cases of epilepsy owe their origin to this wretched and degrading habit; and more than one or two patients have voluntarily confessed to me their conviction, that they had thus brought upon themselves the epileptic paroxysms for which they sought my advice."

Dr. Stapf, in his "Spirit and Scope of Education," says, in talking of the vice of solitary gratification, "The stamp which nature imprints upon the sinner is horrible in the extreme. He is like a faded flower, like a withered tree blasted in the vigour of its youth. He is a walking corpse. All fire and life are extinguished within him; the dumb vice of which he is the slave, leaving nothing behind but feebleness and inactivity, death-like paleness, a withering away of the body, and a general depression of the soul. * * * Natural talents and cleverness give place to slowness of intellect, and, perhaps, to decided stupidity. The soul no longer relishes good and great thoughts, and the imagination is entirely corrupted. * * * Add to all this, the loss of digestion, the corruption of the blood, oppression of the chest, with filthy phlegm, ulcers and corruptions of the skin, emaciation of the whole system, epilepsy, consumption, chronic fever, fits of fainting, and, at last, a premature death."

The next in our list of hereditary diseases is scrofula. Scrofula may be termed a defective constitution, consisting in a deficiency of physical development from weakness of the powers of life, predisposing its unfortunate possessor, in a peculiar degree, to almost all the diseases in the catalogue. Dr. King, in an excellent article on this subjeet in the fifth volume of the "Medical Gazette," says, that "the diseases to which a scrofulous constitution gives rise are, water in the head, tumours, tubercles, abscesses, epilepsy, insanity, hysteria, amaurosis, cataract, fungus, deafness, running at the ears, inflammation of the eyes, enlarged glands in the neck, consumption, disease of the heart, diseases of the stomach and bowels, worms; diseases of the liver, kidneys, bladder, uterus, mesentery; various diseases of the scalp and skin generally; and, lastly, disease of the joints. * * * The human being who comes into the world with a scrofulous constitution is liable to all sorts of petty illnesses, from his birth upwards, till water in the head, or mesenteric disease, or consumption, or disease of the heart, or insanity, put an end to an unfair struggle which ought never to have begun. All men are doomed to die, but a scrofulous child is born and lives in the arms of death. * * * It is supposed that scrofula affects one-fifth of mankind; that one-half of those who are born scrofulous perish in infancy; that a quarter of scrofulous fœtuses die in utero; and that not more than one scrofulous person in five lives to be married." We have here a most fearful description of this disease, or state of constitution; let us see what are its causes. Dr. King says, that "the grand source of scrofula is direct hereditary principle;" but he proceeds to enumerate "certain causes which seem to *originate* scrofula, or the scrofulous constitution or poison, *independent* of hereditary taint." He says, "the first cause is *syphilis;*" that horrible malady which has been called the retalliation of the New World upon the Old, for the cruelties inflicted upon the former by its discoverers, and which was unknown in Europe till the beginning of the 16th century. He gives cases to prove that the offspring was healthy till the parents contracted this complaint; but that children born afterwards were scrofulous, and generally died young, of consumption, or some one or other of the many diseases which scrofula originates. Astruc, a great authority on this subject, says, that "when scrofula is not derived from scrofulous parents, it is invariably derived from syphilis." What a dreadful prey to disease does he become who is the victim of syphilis—that loathsome malady! Scurf of a yellow colour appears in blotches over his skin; his throat and other parts of his body become covered with corroding ulcers; his bones, particularly the

bones of his nose, get diseased and ulcerated; they become brittle, and break on the least accident; at other times they become soft, and bend like a willow: his eyes are affected with itching, pain, redness, ending very often in total blindness; his ears are affected with ringing noises, pains, deafness, becoming carious and ulcerated internally. At length all his animal and vital powers give way, galloping consumption supervenes, the face becomes pale, a hectic flush appears on the cheek, the body becomes emaciated, and death closes the scene. Women who become affected with this disease fall a prey to hysteria, inflammations ending in abscesses and mortification, cancers, ulcers of the womb; they generally either become barren, or subject to abortion; and if they are so unfortunate as to have living children, they are born diseased, scrofulous, consumptive; and, instead of proving a source of happiness to their parents, aid in filling up the bitter cup of human misery which they themselves have prepared.

"The second *originating* cause of scrofula," says Dr. King, "is the excessive abuse and indulgence of the sexual instinct." He gives cases illustrative of this cause, and traces the scrofulous affections—hæmoptisis, ophthalmia, pulmonary tubercles, or worms in children—to the early habitual sexual dissipation of the father. Such cases are an affecting commentary on the remarkable and forcible expression of Job (ch. xx. v. 11), "His bones are full of the sin of his youth." "This," he says, "is one of the many ways in which wealth may prove a curse. Wealth is power, and the first tendency of power is to abuse itself, in all the modifications of which that power is susceptible." "The formation of this product (the seminal secretion)," says Dr. Carpenter, in his excellent Manual of Physiology, "is evidently a great tax upon the corporeal powers; and it is a well-known fact, that the highest degree of bodily and mental vigour is *inconsistent with more than a very moderate indulgence in sexual intercourse;* whilst nothing is *more certain* to reduce the powers, both of *body* and *mind*, than excess in this respect. * * * There can be no doubt that, in the human race, early death is by no means an unfrequent result of the excessive or premature employment of the genital organs; and where this does not produce an immediately fatal result, it lays the foundation of future debility, that contributes to produce *any* forms of disease to which there may be a constitutional predisposition, especially those of a scrofulous nature."

"A third *originating* cause of scrofula," says Dr. King, "is *premature* indulgence of the sexual instinct, and *premature* marriage." "It is remarkable," he says, "that among the German nations which overran the Roman empire, Tacitus relates that it was held disgraceful to indulge the sexual instinct before the age of twenty. And by the laws of Moses, a married man was forbidden to indulge the instinct on the day or night previous to a battle." So well were they aware of the fact, that a considerable loss both of physical and mental power was the consequence. There can be no doubt of the injurious effect of premature marriage, both upon the married couple and their offspring. We have well-known examples of such results, in the diseased, short-lived, and imperfectly civilized nations inhabiting warm climates. If premature marriage had been preceded by indulgence, the effect on the offspring is still more unfavourable; if by syphilis, it is disastrous. The gradual extinction of the higher and aristocratic classes, by the want of direct heirs, and the decline of states, may be generally traced to these sources, engendering a scrofulous, and therefore a perishable constitution.

Marriage *too late* in life is another originating cause of scrofula, and other forms of disease; and we may trace, even in the unconscious infant, the lines of that care which is ushering the decrepit parent to the grave.

Marriages betwixt near relations are another originating cause of scrofula in the progeny. This cause tends to the degeneracy, physical as well as moral, of the human race; to it we may perhaps fairly ascribe that imbecility which has been fatal to royal dynasties, and is even visible at the present day.

Other originating causes of scrofula might be given; but as they do not bear directly upon our present remarks, and as enough has been already said to prove to any rational being the truth of our assertions, we shall pass them over.

In our list of hereditary diseases, we come next to consumption and cancer; but as they appear to be merely forms, though the most fatal forms, of the scrofulous constitution, any additional remarks upon them would be superfluous.

We then come to gout; and it is so well known to be a hereditary disease, and to be generally originated by dissipation, that little need be said upon this head. Like other hereditary diseases, it seems to skip a generation, to reappear in the third. "How many young and interesting persons," says a medical writer, "without any fault of their own—how many juvenile rakes, are seen martyrised and disfigured by the gout, from which their fathers, but not their grandfathers, were free!—a disease which occurs rarely in youth, unless it be hereditary."

How true, then, is the remark of Horace—

"Fortes creantur fortibus et bonis."
(The brave are procreated by the brave and good.)

And as we see that not only may these diseases descend to us from our forefathers, but are capable, chiefly through the influence of moral causes, of being *acquired* by a constitution free from any hereditary taint, and of being transmitted to our children and to our children's children; what a fearful responsibility rests upon every member of society in general, and every parent in particular, to guard sacredly against the causes of these maladies! And how consoling to think, that although we may inherit some of these diseases from our ancestors, yet, by carefully avoiding the exciting causes of them in ourselves, and by the proper moral and physical education of our children, we have it greatly in our own power, primarily to lessen the predisposition to their occurrence which exists, and ultimately to eradicate the taint from our posterity! A knowledge of these hereditary diseases is of the highest importance to every person, whatever his rank and station in life. Such knowledge must increase the desire for the diffusion of moral and physiological training amongst all classes of society. It ought to regulate, in some degree, the choice of a partner for life. Instead of parents making rank or wealth their great aim in the matrimonial alliances of their children, they would infinitely more promote their future happiness, by making the moral and physical constitution of the parties a primary consideration in their approval or disapproval of the union; when both parents have a predisposition to any complaint, the chances of a diseased offspring will be doubled; for this reason, lawful intermarriages between members of the same family are often highly objectionable. This knowledge ought to warn every individual, if his family have a predisposition to any of these diseases, such as scrofula, apoplexy, gout, gravel, &c., not only sedulously to avoid the causes, but to take every means to strengthen his constitution, so as to eradicate, if possible, the hereditary taint.

But hereditary diseases are not the only ones that are produced by moral causes. "Very many diseases," says Dr. Watson, in his Lectures already quoted, "have a mental origin. The domination of violent passions—the frequent recurrence of strong mental emotions—vicious and exhausting indulgences—each and all will sap the strength, and grievously impair the health of the body; and perhaps there is no cause of corporeal disease more clearly made out, or more certainly effective, than protracted anxiety or distress of mind." It is well known to physicians, that moral causes of disease act by diminishing the nervous influence, and weakening the vital energy of the corporeal powers; and that whatever tends to weaken that vital energy, is a most powerful predisposing cause of disease. Those whose vital energy is weakened by the abuse of stimulants, and other exhausting indulgences, fall the first victims to fever, to cholera, and to all contagious epidemics. What a train of diseases follow the abuse of ardent spirits! Dr. Watson, in enumerating the causes of apoplexy, says, "and large obser-

vation of the habits of those who fall victims to this terrible malady, leaves no room for doubting that intemperance often paves the way for its invasion. The continued abuse of ardent spirits, in particular, lays the foundation of many of those morbid conditions of the sanguiferous system, and of the viscera, which constitute the predisposition we are now considering." Diseases of the liver, of the stomach, of the brain, of the kidneys, of the bladder, and of the eyes, gout, tremors, palpitation of the heart, hysteria, epilepsy, sterility, emaciation, premature old age, ulcers, melancholy, madness, delirium tremens, are all given in detail by Dr. Macnish, in his "Anatomy of Drunkenness," as arising from intemperance; and he says, "there are still several others which have not been enumerated—nor is there any affection incident to body or mind, which the vice does not aggravate into double activity. The number of persons who die in consequence of complaints so produced, is much greater than unprofessional people imagine. * * * Dr. Willan, in his Reports of the diseases of London, states his conviction, that considerably more than one-eighth of all the deaths which take place in persons above twenty years old, happens prematurely through excess in drinking spirits."

We have said enough to satisfy any reasonable and reflecting mind, that moral causes exert a most powerful influence in the production of disease; and enough to show the necessity, even from no higher motive than a desire of temporal happiness, of shunning the slightest deviation from those precepts of virtue, which are so beautifully inculcated by our Divine religion. We have seen the external world adapted with the greatest exactitude to the physical well-being of man; and we cannot help pitying the miserable blindness or ignorance of him who cannot see and admire that wonderful adaptation of means to ends, which so visibly marks infinite power, intelligence, and design, on the part of the Creator. In the same way we may see, in the Christian religion, its beautiful adaptation to the moral well-being of man, in all the various circumstances in which he may be placed; and sincerely do we pity those who can suppose it possible that such precepts of self-denial and virtue could have arisen, in a comparatively rude and corrupt age, without a Divine origin; with equal reason might it be asserted, that the world created itself.

## POLITICAL ECONOMY.

### CHAPTER II.

#### VALUE.

THE first result of the divisional system of employment, says Mr. John Little, is the accumulation, in the hands of the producer, of a surplus beyond the amount of his own necessities of the commodity produced; thus, the man whose industrial energies are solely occupied in the production of cloth, accumulates more of that commodity than is necessary for his own personal use. The baker also accumulates a greater quantity of bread than he himself requires; but the weaver wants bread and the baker wants cloth, hence the former with the surplus of his cloth, and the latter with the surplus of his bread, are necessarily and naturally led to effect a mutual exchange, the baker supplying the weaver with bread, and the weaver supplying the baker with an equivalent, that is, with equal value, in cloth. In the same way the tanner, the tailor, the shoemaker, the hatter, the hosier, &c. &c., accumulating their respective productions beyond the extent of their personal necessities, part with the surplus for their value in other commodities which their varied necessities demand. These mutual transactions between man and man, or between nation and nation, are, in commercial language, termed "barter," which means the exchanging of one commodity for its value in another. We are thus brought into contact with the word "*value*" as associated with barter, or exchange of commodity for commodity, and which is by far the most important in the lexicon of political economy. As the misapprehension of what value really is and what it is not, has proved a most fertile source of error in the conclusions of even the most eminent writers on political and monetary science, and of the most disastrous consequences in every department of industrial practice; and, moreover, as a correct knowledge of its true substance is inseparable from anything like an intelligent apprehension of the first principles of political economy, a demonstration of what constitutes the essence of the element referred to is indispensably necessary. The air which we breathe is essential to every moment's existence of both the animal and vegetable creation, yet, because all can enjoy its possession *gratuitously*, or without the expenditure of *labour*, it is, as a commodity of barter, *valueless*. Again, although the light of a candle is to the light of the sun as a drop of water is to the oceans of the universe, yet a single rushlight is, as a commodity of exchange or barter, of more value than the whole mass of light that floods away to a thousand worlds from the great centre of our solar system. In other words, while the rushlight *does* possess value as a commodity of barter, the light of the sun does *not;* but the former is possessed only through the medium of labour, the latter is received by man *gratuitously*, or *without labour;* that is to say, that which costs *labour does* possess value, and that which cost *no* labour does *not* possess value, as a commodity of barter. But suppose that the rushlight, like the light of day, could be got without any outlay of labour, it would then, as an article of barter, be valueless also; hence, possessing labour it possesses value, possessing *no* labour it possesses *no* value. Again, a small quantity of flax, whose original labour-cost is only threepence, after being manufactured into a certain description of lace, possesses in the market a value in money of twenty pounds. Now, as nothing but *labour* has been absorbed by the flax since its value was threepence, it follows that the additional value, amounting in money to £19. 19s. 9d., which it now possesses, is derived from and composed of the additional *labour* expended on the flax in the process of its manufacture into lace. The conclusion, therefore, that *labour*, and labour only, constitutes the true essence of value is unavoidable.

But although the truth, that the essence of value is composed of labour, has been clearly recognised in the school of political economy, yet an *alloy*, that is to say, *something else than labour* or value, has most unaccountably been permitted undiscernedly to mix itself up with that element, and which has not only destroyed its distinctive character, but formed the producing cause of incalculable havoc and confusion in every form of industrial pursuit. We refer to the confounding of value with *price*, to the mixing up of that which is *unchanging* with that which is *fluctuating*. Value, as has been proved, being composed of *labour*, it is evident that, if *anything else than labour* is added to or recognised as value, the latter is, *as value*, in the same proportion *alloyed* and rendered *fictitious*. Thus, suppose that the value of a quarter of wheat in the hands of the farmer is 60s., and that it fetched that sum in the market, then the *value* of the wheat and its *price* would be *equal*. Again, suppose that, in consequence of a great and sudden demand for wheat, without a corresponding increase of supply, the farmer receives for the same wheat 120s. per quarter, its price would thereby be *doubled*, but that which constituted its true value would not be increased by a single farthing, because the increase of its price from 60s. to 120s. was derived *not* from *labour*, which *alone* constitutes true value, but from a surplus of demand over supply, which is *not* value because it is *not labour*. On the other hand, if, instead of an increase of supply over demand, the demand, in consequence of some sudden diminution of the consuming population, fell so much short of the supply, that the same wheat falls from 60s. to 30s. per quarter in the market, in that case the price of the wheat would suffer a diminution of *one-half*, but its real value would still be the same, viz. 60s., because the reduction in the price of the

wheat from 60s. to 30s. was derived, *not* from a corresponding reduction in the *labour* which the wheat had cost the farmer, but from *something else*, viz., from a deficiency of demand for wheat in proportion to the supply. In the one case, the price of the wheat rose 60s. above its value, that is, above its labour-cost; in the other it fell 30s. below its value or labour-cost, but the value did not rise above *itself* at the one time, and fall below *itself* at the other. It could no more do so than a yard length could be two yards at one time, and a half yard at another. Now the practical error to which we refer makes value and price one and the same thing, and consequently confounds that which is *fixed* with that which is *fluctuating*. In the case of the wheat just mentioned, it would say that its value was at one time 60s., at another time 120s., and at another only 30s.; while, in reality, the value never for a moment either rose above or fell below 60s.; the 120s. on the one hand, and the 30s. on the other, were the *prices* to which it rose and fell—not the value, which was always 60s.

It may here be proper to refer to a practical difficulty which has always been experienced in comparing one kind of labour with another; the labour of a farmer's servant, for example, with the labour of a working jeweller, or the labour of a common blacksmith with the labour of a professor of mathematics.

Labour and value, as has already been demonstrated, are *one* thing—are convertible terms; hence, if one commodity be equal in value to another commodity, the two commodities must possess the same quantity of *labour*. Thus, if a hat and a pair of shoes have in their production respectively absorbed an equal quantity of labour, then they are equal in value; and equal in value, the remuneration due to the producer of the hat will be exactly equal to the remuneration due to the producer of the shoes. Or, if the hat in its production cost double the labour which is required to produce the pair of shoes, then the value of the hat will be double the value of the shoes; and if double the value of the shoes, the wages due to the manufacturer of the hat will be twice the amount due to the manufacturer of the shoes. The wages being thus determined and measured by the *amount* of labour performed in the production of each of their respective commodities, it follows, that the proper remuneration due to each depends, not upon the time employed, but on the *amount* of labour performed by each during a specified time. Thus, if the labour performed by the hatter in ten hours is greater or more dense than the labour performed by the shoemaker in the same space of time; then, in proportion as the labour of the former is greater or more dense than that of the latter, in the same proportion is the remuneration due to the hatter greater than the remuneration due to the shoemaker. Illustrative of the principles by which the *density* of the various forms of labour is ascertained, suppose that, between Edinburgh and Glasgow, there are three different roads of *equal* length, say 40 miles each, and that the difficulties in travelling by the second road are two times greater than those by the first, and also that the difficulties which present themselves to the traveller by the third route, are not only equal to those occurring on the second, but imposts amounting to £1, or 6d. per mile, are leviable on the third, with which the other two are not burdened. Further, if I engage three messengers to walk the distance between the two cities, one by each road, and if the messenger by the first road is entitled to 6d. per mile, the one by the second road is entitled to 1s., and the one by the third to 1s. 6d. per mile, because the difficulties in travelling by the second road are twice as great as those by the first, and because, in travelling by the third road, the physical difficulties are not only equal to those of the second, but the messenger by the third is taxed at the rate of 6d. per mile, with which the other two are not burdened. Thus, while the lengths of the roads travelled by each are *equal*, I remunerate the messengers by very different amounts, and yet the proportions are in harmony with the principles of the most rigid justice to each, because I pay them according to the amount of *value* received from each, that is, according to the amount of *labour* performed by each; value and labour being *one* thing.

In the same way, the just remuneration payable to the various parties travelling by the various industrial routes, is in proportion not to the time occupied, but to the amount or density of labour performed by each during a specified period. Suppose that thirty years form the average length of man's industrial existence, and that the difficulties in travelling over that period by a man as a working carpenter, are equal to the difficulties encountered in the same length of time by another man as a working agriculturist, but that, in order to qualify him for his professional journey, the carpenter is obliged previously to labour gratuitously for five years as an apprentice, which the agriculturist is not required to do; besides, he is subjected to an outlay for tools of £5 per annum, from which the agriculturist is free. Then, if the agriculturist is entitled to £40 per annum, or £1,200 for 30 years, the carpenter is entitled to £56. 13s. 4d. per annum, or £1,700 for 30 years; that is, he is justly entitled to 1s. $\frac{3}{4}$d. per day, or £16. 13s. 4d. per annum, or £500 for 30 years, *more* than the agriculturist, because duties are leviable (to use the former figure) on the industrial road of the carpenter, amounting to £500, equal at £40 to $12\frac{1}{2}$ years' labour, which are not leviable on the agriculturist. In like manner a third party, whose profession requires an educational or some other qualification, is entitled to an additional remuneration, corresponding to the cost, in money and labour, of that qualification, the money being here only another name for labour, because the money is purchased with labour. So on with every other industrial pursuit.

Thus, if left to the natural action of natural laws—that is to say, if labour or value is weighed with *labour* or *value*, and with *nothing else;* or if labour or value is measured with *labour* or *value*, and with *nothing else*—the difference between the amount or density of labour or value in one profession, and the amount or density of labour or value in another, is at once exposed, and, consequently, the true proportion of remuneration due to each is determined.

## DEMAND

### THE CAUSE OF, AND CO-EXTENSIVE WITH, PRODUCTION.

Anterior to the division of labour, and to its offspring, barter, the primary cause of production had its existence located in the wants or necessities of mankind. That the expenditure of labour, for ex mple, to procure the possession of food or of water, of sheltei or of raiment, had its generating cause in the wants of the producer for these various commodities. Now, the laws of nature being, like their Author, unchanging and unchangeable, and because the wants of men were the primary cause of the outcoming of industrial exertion prior to the division of labour and barter, production under that system must still be the result of the same cause; but, apart from any analogical deductions, the truth is quite palpable, that the concentration by any individual of his industrial energy on the production of any one commodity, does not nor cannot destroy or lessen the realisation of his need for other commodities. That as the farmer, merely because he confines the application of his energy to agricultural pursuits, does not destroy his requirements for cloth, or for shoes, or for any other article, so neither does the confinement of the industrial energies of any other individual to any other pursuit, prevent the outgoing of his necessities for other commodities than those which he himself is employed to produce. No doubt the change to the divisional system of employment from its primitive opposite was accompanied by immense results; but these were social in their character, and in no way did they touch the relative positions which demand and production, as cause and effect, originally, and by the laws of nature, occupied towards each other. Hence, under the operations of the division of labour at the present day, the production of cloth or of coals, of iron, of ships, or of any other commodity, has its existence in the wants of society for these commodities, just as truly as the cause of the exer-

tions of the savage, in fishing and in hunting, thousands of years ago, had its existence in the cravings of his appetite for the food that perisheth. The school of political economists, which, on the contrary, asserts that, naturally, production is the cause of demand, confounds demand with its *manifestation*—a cause with its *expression*. It is true, there exists a certain description of commodities whose production, at first sight, *appears* to form the source of the demand for their use by the public. For example, the demand for a book might appear to a superficial thinker to be the consequence, and not the cause of its author's labours; but such, in reality, is not the case. If the public mind were omniscient, and acquainted with every word and thought and truth which the volume contained, there would, it is evident, not only be found no purchaser of the book, but there would exist no *reason* for its production by the author; because the knowledge which its perusal was intended to convey to the reader was already in his possession, and that it brought for his reception only that which his mind already embraced, an article, so to speak, with which he was already supplied. Hence the true essenee of the demand for the work; the true cause of its production consists in his *prior ignorance* of its contents on the part of the public mind; and the mere aet of purchasing or ordering the book from the publisher, which is posterior to its production, is only the *outcoming* of that ignorance—that is to say, it is not the demand itself, but only its *expression* and *manifestation*.

But, under the stage of industrial development, which includes the division of labour and the practice of barter, and which is antecedent to the employment of what is called money, DEMAND, *by the laws of nature*, is CO-EXTENSIVE WITH PRODUCTION. Every one who is a seller, is forced, by the very act of selling, to become a buyer to the same extent. He buys only in proportion as he sells, and sells only in proportion as he buys. The sale includes the purchase, and the purchase includes the sale. They are *one and the same act*. Thus, if a farmer bring for sale to the market 100 quarters of wheat, he brings with him a demand for other commodities equivalent to 100 quarters of wheat; because the value of the commodities which he purchases is measured by the value of the wheat which he sells or exchanges for these commodities, and hence the value he takes *into*, and the value he takes *out of*, the market are equal; consequently, his production for, and his demand in, the market are equal. If he increase or diminish the former, he increases or diminishes the latter in the same ratio. Again, if America ship to the English market 10,000 bales of cotton wool, English productions will be the subjects of American demand to the extent of the value of that wool; because the value of the cotton thus sent for exchange by America to England, expresses the value of the commodities which England is required to export to America in return. For the same reason, if Great Britain export to France any quantity of British commodities, France exports to Britain an equivalent in French goods; hence, in the French market, the British supply of British goods and the British demand for Freneh goods are equal; and *vice versa* in the British market, the French supply of French commodities and the French demand for British productions are equal. To whatever extent of value, therefore, one country exports to another, to the same extent the former imports from the latter; and hence the production and demand in every market in the world, emitting either from individuals or from nations, are abstractly equal.

Thus, by the spontaneous and unrestricted laws of nature, individual freedom of action is combined with universal association, individual independence with mutual reliance, the happiness of one with the happiness of all. While each man by being himself created a source of industrial power, a source of true wealth, that is, by inheriting, in virtue of the constitution of his own being, the means of providing for his own necessities, is thereby relieved from the degradation of dependence on others; yet one man cannot promote his own interests, without at the same time, and by the same act, and in a corresponding degree, promoting the interests of others; and that he can neglect the welfare of society, only by neglecting his own—that the husbandman, for example, can supply himself with cloth, and shoes, and tea, and coffee, sugar, &c., only by supplying others to the same extent with corn; and that, on the contrary, he can cease to supply the public with corn, only by depriving himself of raiment, tea, coffee, and other commodities—that the weaver and the shoemaker can command bread and butchermeat, hats, hosiery, furniture, &c., &c., only by giving their equivalent in their own productions to others, and that their refusal to provide the public with eloth, and boots, and shoes, is equivalent to the non-possession of food, of furniture, of groceries, &c., &c., by themselves. In like manner, one nation or one country can enjoy the productions of other nations and other countries only by reciprocating the benefit. The people of Great Britain can enjoy in their own home the products of France, of Spain, Italy, Russia, Asia, Africa, and America, only by correspondingly adding to the temporal welfare of the inhabitants of these various countries; and just in proportion as the people of France, of Spain, of Italy, &c., refuse to minister to the temporal welfare of the British, in the same proportion do they refuse to minister to their own. In short, such is the nicely-adjusted and beautiful arrangement of the industrial mechanism, created and sustained by the perfect and irrevocable laws of nature, that while it requires for its propulsion the employment of no artificial organisation, the execution of no man-made laws, but demands for the spontaniety of its movements, and for the certainty of their results, only freedom from human interruption—freedom from the consequences of human presumption and human ignorance — it establishes harmony and good-will among all, by demonstrating the oneness of the interests of all—it dispenses universal justice, by rewarding the industrious and punishing the indolent—it blesses the creature and glorifies the Creator—it insures to the former the reality of temporal comfort and temporal happiness, and wafts up to the latter the continual breathings of gratitude from the heart of universal humanity.

## FAIRBAIRN'S PATENT TUBULAR CRANE.

*(Official Catalogue, Class V., No. 417.)*

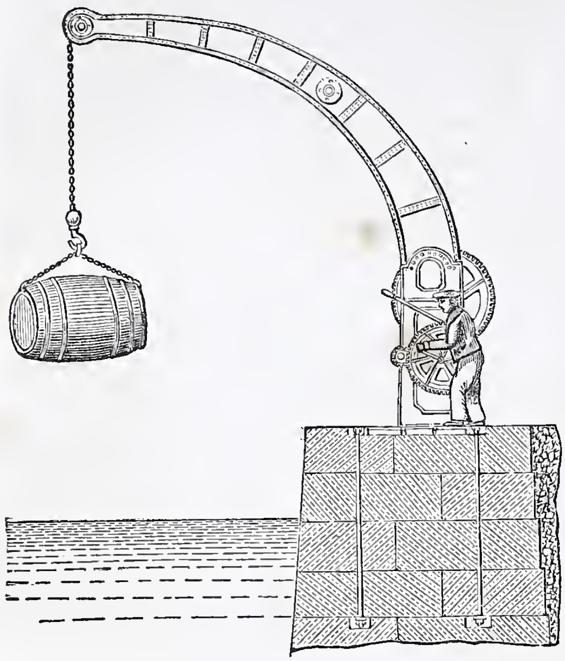
THE engraving represents a side view of the crane, with a portion of the side removed to the foot, in order to show the cast-iron cylinders built in the masonry, the rollers which eneircle the body of the crane and support the stem vertically, with its rollers and bearings acting against the interior recess of the large circular plate *a a*, between the plate and the frame, which embraces the crane in a ring which contains the rollers, giving a rotatory motion to the crane in any direction. Immediately above the rollers is a platform of 12 feet in diameter attached to the stem, on which the men stand to work the crane. This platform also enables a man, by turning a handle, to move the crane round in any direction at pleasure.

We subjoin some remarks on this crane, contained in a report of the British Association, communicated by Sir David Brewster:—

"These structures indicate some additional examples of the extension of the tubular system, and the many advantages which may yet be derived from a judicious combination of wrought-iron plates, and a careful distribution of the material in all those constructions which require security, rigidity, and strength.

"The projection or radius of the jib of these cranes is 32 feet 6 inches from the centre of the stem, and its height 30 feet above the ground. It is entirely composed of wrought-iron plates, firmly riveted together on the principle of the upper side being ealculated to resist tension, and the under, or concave side, which embodies the cellular construction, to resist compression. The form is correctly that of the prolonged vertebræ of the bird from which this machine for raising weights takes its name; it is truly the neck of the crane tapering from the point of the jib, where it is 2 feet deep by 18 inches wide to the level of the ground, where it is 5 feet deep and 3 feet 6 inches wide. From this point it again tapers to

a depth of 18 feet under the surface, where it terminates in a cast-iron shoe, which forms the toe on which it revolves. The lower or concave side, which is calculated to resist compression, consists of plates forming three cells, and varying in thickness in the ratio of the strain; as also the convex top, which is formed of long plates chain-riveted with covers; but the sides are of uniform thickness, riveted with T iron, and covering plates $4\frac{1}{2}$ inches wide over each joint. This arrangement of the parts and distribution of the



Five-ton Tubular Crane, $\frac{1}{36}$ scale.

materials constitute the principal elements of strength in the crane. The form of the jib, and the point at which the load is suspended, is probably not the most favourable for resisting pressure. It nevertheless exhibits great powers of resistance; and its form, as well as the position, may safely be considered as a curved hollow beam, having one end immoveably fixed at A, and the other end, C, the part to which the force is applied. Viewing it in this light, the strengths are easily determined, and taking the experiments herein recorded, we have by the formula $W = \frac{A\,d\,C'}{e}$ a load of 63 tons, the weight it would require to break the crane. With 20 tons the ultimate deflection was 3·97—·64 of a permanent set = 3·33 inches, the deflection of the jib due to a load of 20 tons. The following constitute the experiments made at Keyham Docks:—

"Experiments made to ascertain the resisting powers of a new wrought-iron tubular crane, erected at Keyham Dockyard, Devonport, November 8, 1850:—

| Weight of Cargo in Tons. | Deflection at the point of the jib in inches. |
|---|---|
| 2 | ·32 |
| 3 | ·50 |
| 4 | ·65 |
| 5 | ·90 |
| 6 | 1·05 |
| 7 | 1·20 |
| 8 | 1·35 |
| 9 | 1·50 |
| 10 | 1·70 |

With 5 tons suspended the crane was turned completely round, without any alteration in the deflection.

With this weight the crane was again turned round; the deflection in eight minutes increased to 1·85 inches, when it became permanent after sustaining the load during the whole of the night, a period of about 16 hours.

"On 9th November the experiments were resumed as follows:—

| Weight of Cargo in Tons. | Deflection at the point of the Jib in Inches. | Weight of Cargo in Tons. | Deflection at the point of the Jib in Inches. |
|---|---|---|---|
| 11 | 2·05 | 16 | 3·00 |
| 12 | 2·22 | 17 | 3·20 |
| 13 | 2·40 | 18 | 3·50 |
| 14 | 2·60 | 19 | 3·73 |
| 15 | 2·80 | 20 | 3·97 |

On again turning the crane round with a load of 20 tons, there was no perceptible alteration in the deflection; and the permanent set, after removing the load, was ·64 inches.

"From the above experiments, it appears that the ultimate strength of the crane is much greater than is requisite either in theory or practice, and, although tested with nearly a double load, it is still far short of its ultimate powers of resistance, which it will be observed are five times greater than the weight it is intended to bear.

"The advantages claimed for this construction are its great security, and the facility with which bulky and heavy bodies can be raised to the very top of the jib, without failure. It moreover exhibits, when heavily loaded, the same restorative principle of elasticity strikingly exemplified in the wrought-iron tubular girder These constructions, although different in form, are nevertheless the same in principle, and undoubtedly follow the same law as regards elasticity and their powers of resistance to fracture."

## LARGE HYDRAULIC PRESS,

USED IN RAISING THE BRITANNIA TUBULAR BRIDGE, EXHIBITED BY THE BANK QUAY FOUNDRY COMPANY, WARRINGTON.

*(Section II., Class V., No. 412.)*

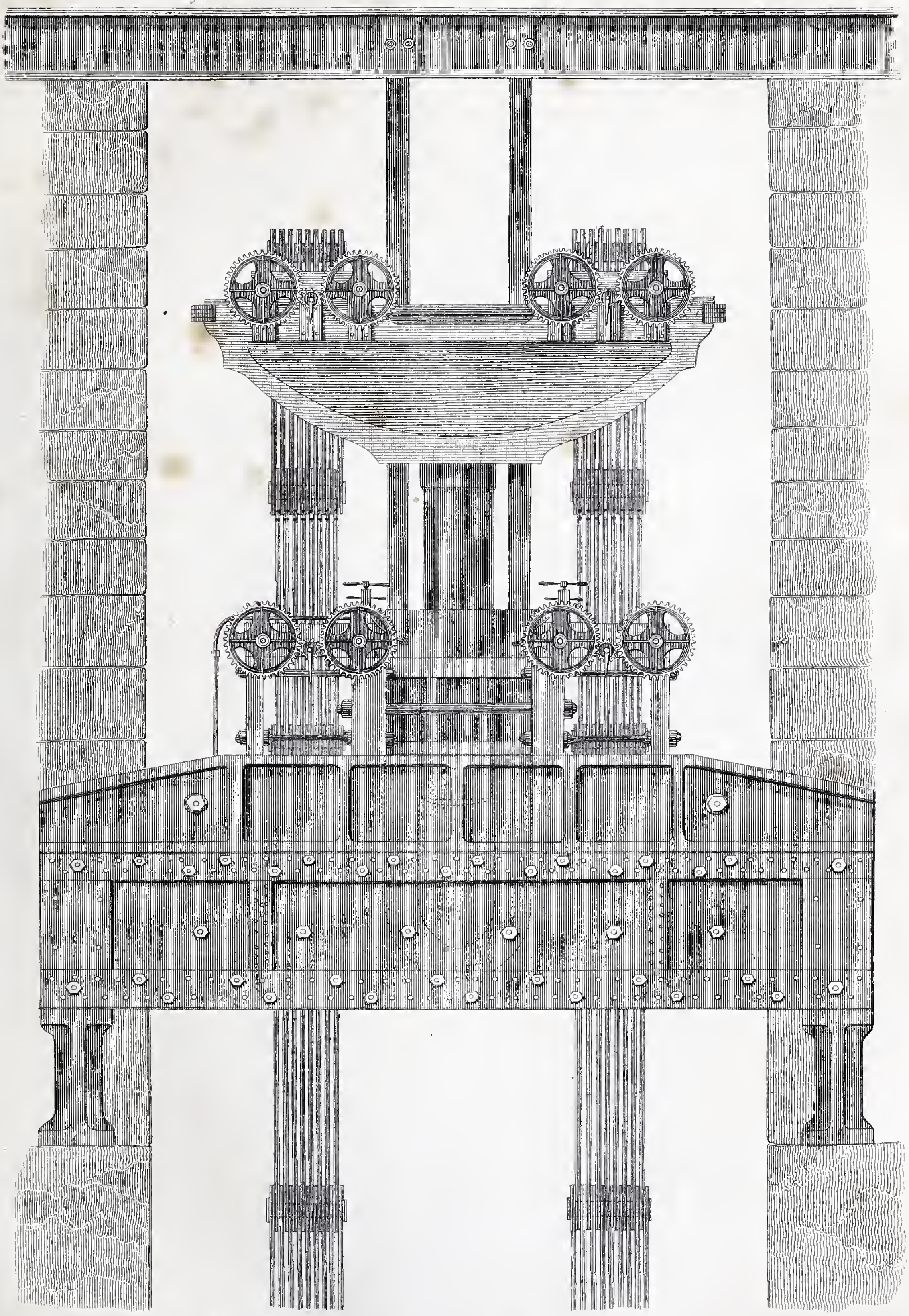
Explanation of the engravings:—Fig. 1 represents a front elevation of the press; fig. 2 an end elevation; fig. 3 shows its application in the act of raising the Britannia tube, with the latter partly lifted.

A—Wrought-iron Sandwich girders, weighing 12 tons each.
B B—Cast-iron beams, 5 tons each.
C—Jacket of cast and wrought-iron, weight 8 tons.
D D—Cylinder, cast-iron, weight 15 tons.
E—Ram, 3 tons 13 cwt.
F—Crosshead, cast-iron, 13 tons.
G G G G—Clamps.
H—Chains.
I I—Guide rods, wrought-iron.
K—Guide rod beam.
L L—Valves.
M—Distance pieces between wrought-iron Sandwich girders.

The internal diameter of the cylinder is 22 inches, the diameter of the ram is 20 inches, the external diameter of the cylinder is 42 inches, external length 9 feet $1\frac{1}{2}$ inch; thickness of metal 10 inches; the water is forced into the cylinder through a pipe and valve L, the press is placed in the jacket C, and rests upon the cast-iron beams B B, which again are supported by the wrought-iron beams A A; the cast-iron crosshead F has wrought-iron links let in at the top, for the purpose of strengthening the part subject to tensile strain; the sides of the jacket also are strengthened with wrought-iron slabs, weighing 30 cwt. each, expanded first by heat and then fitted-on hot, and allowed to contract. To cast the cylinder, it required 22 tons of fluid metal, the additional quantity beyond its finished weight being required for the head, or git, which weighed $2\frac{1}{2}$ tons. This head, or git, was kept in a fluid state for six hours after the run, by replacing the material after it became stiff, with metal fresh from the furnace, and of the highest attainable temperature, for the purpose of supplying the space in this immense body of metal below, consequent upon the contraction. In three days afterwards the cylinder was partly denuded of its outer coat of sand, when it was found red-hot: in seven days it was lifted from the pit in which it was cast, and in ten days, or 240 hours, it was sufficiently cool to be approached by men well inured to heat, for the purpose of dressing the remaining sand off it.

The A A beams, for supporting the press, consisted of six vertical ribs of boiler plates, $\frac{5}{16}$ths thick, united by vertical strips, to preserve them in form; the $2\frac{1}{8}$ inch spaces between ribs were filled with American elm, so that the vertical rib was a sandwich of elm and iron. The top and bottom flanges were each formed by twelve

Fig. 1

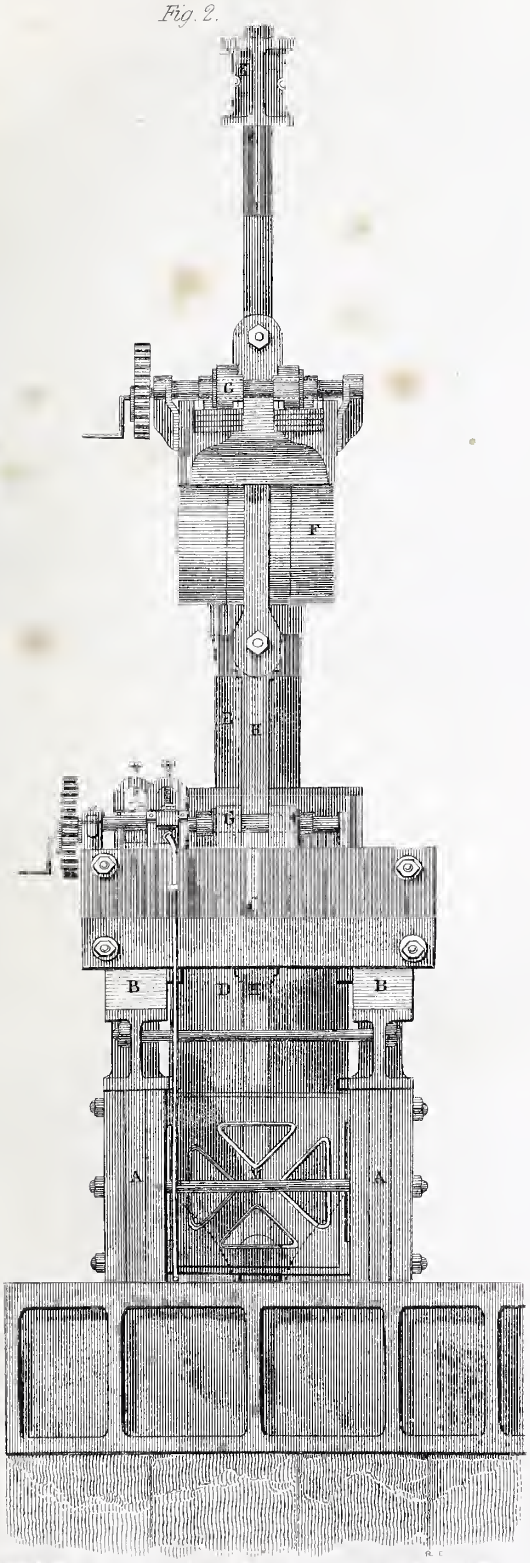


GREAT HYDRAULIC PRESS EMPLOYED IN RAISING THE BRITANNIA TUBULAR BRIDGE.

EXHIBITED BY THE BANK QUAY FOUNDRY C^o. WARRINGTON.

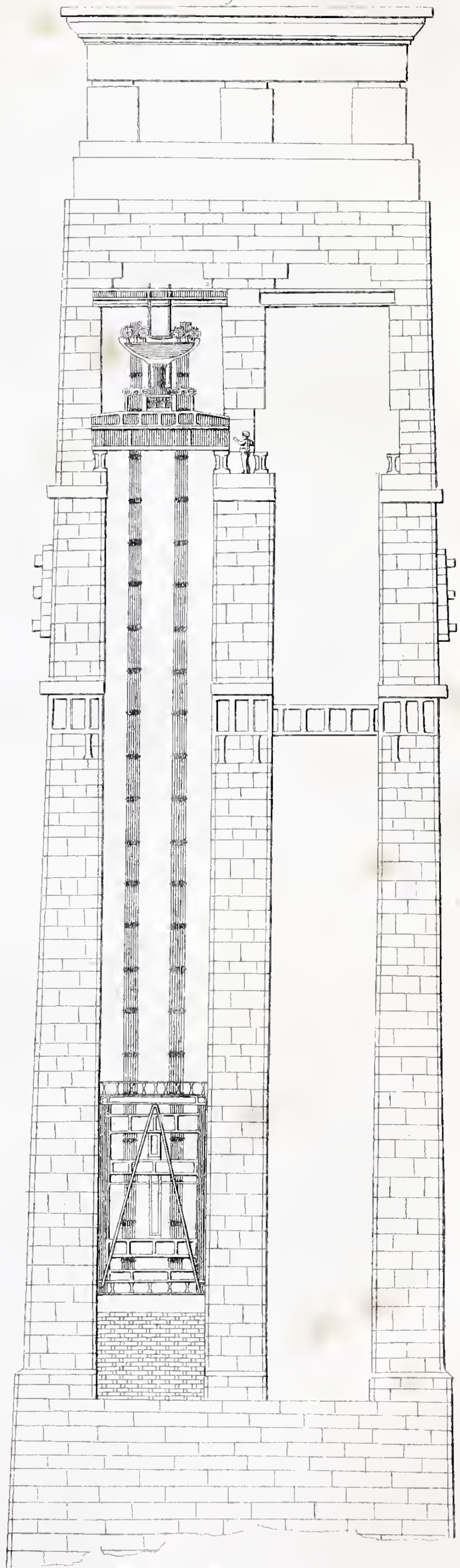
TO WHOM A PRIZE MEDAL WAS AWARDED AT THE GREAT EXHIBITION. Section II. Class V. N^o. 412.

*Fig. 2.*



THE PRESS SHOWN IN OPERATION—THE TUBE PARTLY LIFTED.

*Fig. 3.*

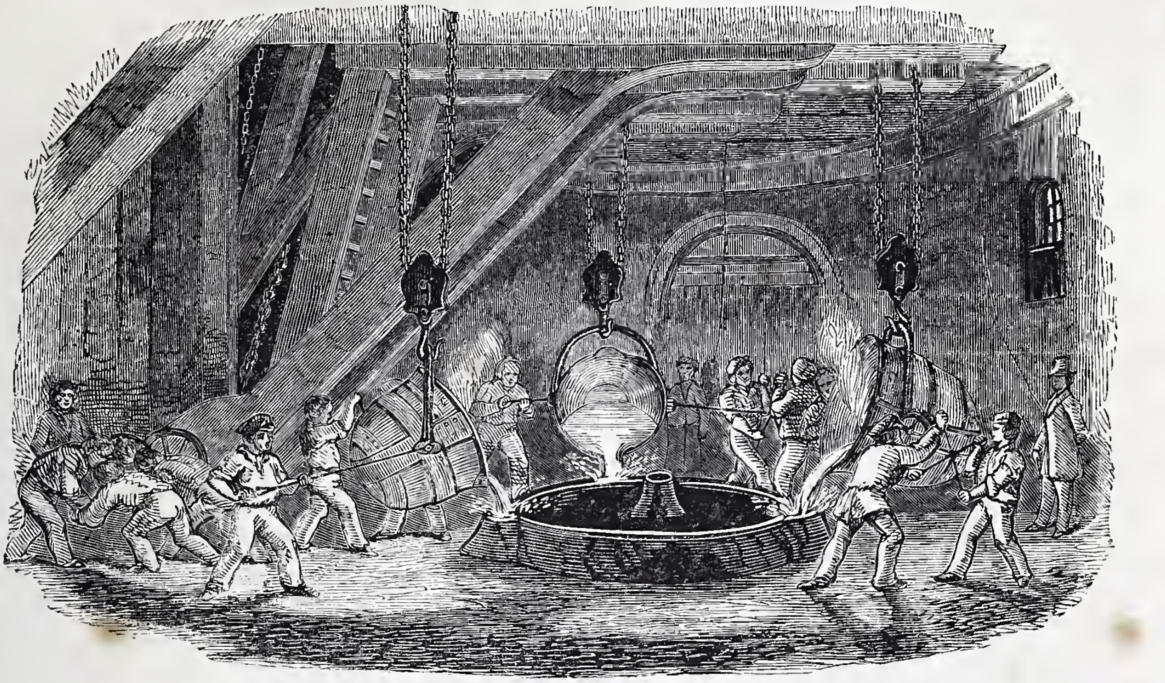


END ELEVATION.

wrought-iron bars, extending the whole length of beam. The top bars 7 inches wide, and the bottom bars 9 inches by $1\frac{1}{8}$ inch; the whole riveted together. The weight of each girder was 12 tons. In order to prevent the crushing at the ends, cast-iron plates were inserted instead of the wood.

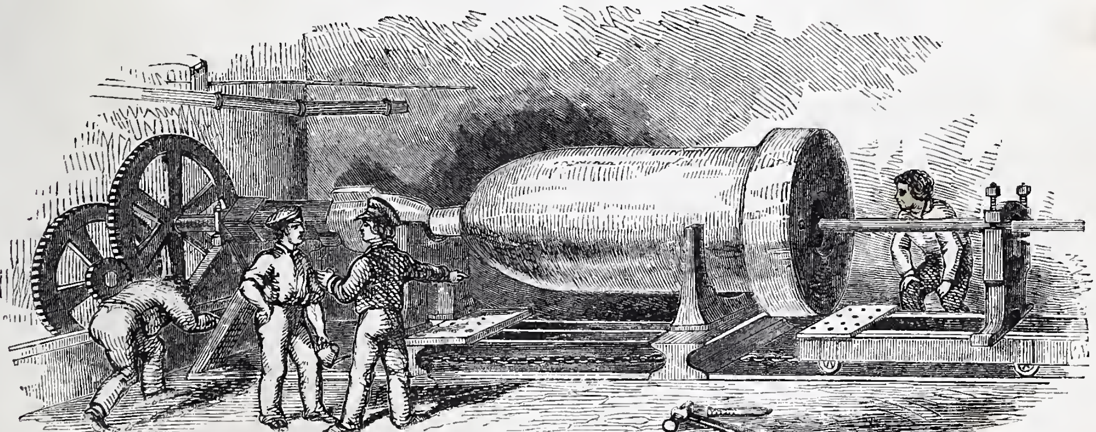
The weight actually supported by one pair of beams was 1,177 tons, but they were capable of sustaining 2,000 tons. The length between the bearing was 17 feet 4 inches. The ram was cast hollow and turned to bed truly, beneath the crosshead, which was bored to receive it. The crosshead was guided by two wrought-iron rods, 6 inches diameter, fitted in sockets on the top of the press, and keyed above into a cast-iron girder, K, built in the masonry.

There were two sets of clamps; the one placed on the crosshead,



Casting the Cylinder of the "Britannia Press," at the Bank Quay Foundry, Warrington.

and rising with it, was immediately used for lifting the chain and tube; the under set was fixed on the cast-iron girders which support the press, and was used for securing the chain at the end of each lift, while the press was lowered, and the upper set of links removed; they are in all respects similar to each other. The wrought-iron clamping cheeks are slotted to fit closely beneath the slotted shoulder in the head of the links; they are withdrawn or closed by right and left handed screws, on turning which the cheeks recede from each other, or are drawn into close contact with the chain. To insure a parallel action, the screws are moved simultaneously by a winch and



Boring the Cylinder.

gearing; they are thus easily worked by one man. Thus at each stroke of the press the tube was raised 6 feet, the time occupied in one lift being usually from 30 to 45 minutes.

The lifting chains were manufactured by Messrs. Howard and Ravenhill: the clamps and valves by Messrs. Easton & Amos. The superintendence of the designs and construction of this machinery were entrusted by Mr. Robert Stephenson, the engineer, to Mr. Edwin Clark.

The greatest weight lifted by the press at the Britannia bridge was 1,144 tons; the quantity of water used for each 6 feet lift $81\frac{1}{2}$

gallons. "The pressure at three tons per circular inch equals 3·819 tons per square inch, which would raise a column of water 5·41 miles in height; this pressure would, therefore, be sufficient to throw water over the highest mountains on the globe." This extraordinary fact is derived from Mr. Edwin Clark's work on the Britannia and Conway bridges. The following additional extract shows indirectly the vast power of this machine:—

"If it were required that 1 lb. should raise the tube, or 2,000 tons, then one arm of the lever must be 448,000 times as long as the other; but if the 1 lb. move through a space of 1 inch, the tube will be only lifted $\frac{1}{448000}$th part of an inch; and in order to raise the tube 100 feet, the pressure of 1 lb. must be continued through a space of 83,522 miles; and, conversely, a pressure of 2,000 tons through a space of 100 feet, would raise 1 lb. 83,522 miles; thus the descent of a clock-weight through a space of 6 feet overcomes the friction of the machine, and moves the extremity of an ordinary seconds-hand through a space of two miles in a week, and the descent of the tube to the water would maintain the going of an ordinary clock for 240,000 years," or the power expended by the press in lifting the tube 100 feet, if applied to an ordinary clock, would work it for a period of 240,000 years.

After the first tube was raised, the cylinder met with an accident, described in the following terms by Mr. Clark:—

"In a little more than a fortnight after this operation the presses were removed ready for raising the next tube. They were lowered and raised again by means of capstans, with an 8-inch rope; and in this operation another accident occurred with the unlucky press. The cylinder was lowered from a cat-head at the top of the tower; the rope from the blocks led to a capstan on the beach, on which three turns only were taken; while the cylinder, weighing 15 tons, was suspended at an elevation of 140 feet above the water, the rope unexpectedly surged on the capstan, and was dragged out of the hands of the men who were holding it; the cylinder descended with fearful velocity, dragging the rope through the block tackle and round the capstan, which fortunately became palled by the jerk. As the velocity increased, the cat-head in the tower gave way, and the cylinder fell on the stone shelf below, fracturing the masonry, and gliding off 50 or 60 feet into the Straits. Several men were injured, and a sailor who was serving out the coil of rope was dragged round the capstan and killed. None of the tackle was broken, and the press was easily raised by the ropes attached to it, and was found to be uninjured by the fall."

## NATURAL PHILOSOPHY AND CHEMISTRY

### CHAPTER VII.

GENERAL PROPERTIES OF LIGHT—REFLECTION—OPACITY AND TRANSPARENCY—SHADOWS.

Light is the agent whose action on the eye originates the sensation of vision—that is, the sensation by which we are made conscious, through the eye, of the presence of external bodies situated beyond the range of touch; and which in familiar language we denominate *seeing*. As a physical agent, "its utility may be judged of by the reflection, that if man had been compelled to supply his wants by groping in utter and unchangeable darkness, even if originally created with all the knowledge now existing in the world, he could scarcely have secured his existence for one day. Without light, the earth would indeed have been an unfit abode even for grubs, generated and living always amidst their food. Eternal night would have been universal death. Light, then—while the beauteous garb of nature, clothing the garden and meadow—glowing in the ruby—sparkling in the diamond—is also the absolutely necessary medium of communication between living creatures and the universe around them. A man, whenever placed in light, receives by the eye from every object about him—nay, from every point in every object, and at every moment of time—a message of light to tell him what is there, and in what condition. Were he omnipresent, or had he the power of flitting from place to place with the celerity of the lightning's flash, he could scarcely be more promptly informed. Then in many cases where distance intervenes not, light can impart at once knowledge, which by any other conceivable means could come only tediously or not at all. Thus, where the illuminated countenance is revealing the secret workings of the heart, the tongue would in vain try to speak, even in long phrases, what one smile of friendship or affection can in an instant convey; and had there been no light, man never could have suspected the existence of the miniature worlds of life and activity, which even in a drop of water the microscope discovers to him; nor could he have formed any idea of the admirable structure of many minute objects. It is light again which gives the telegraph, by which men readily converse from hill to hill, or across an extent of raging sea,—and it is light which, pouring upon the eye through the optic tube, brings intelligence of events passing in the remotest regions of space."—*Arnott.*

As a chemical agent, light is conspicuous in a variety of natural and artificial processes. In vegetation it is indispensable; and by its assistance, growing plants are enabled to decompose carbonic acid, and assimilate its basis (carbon) for the purpose of nutrition. Without its influence, the green colouring matter is not elaborated; the plant which grows in the dark is blanched, weakly, and inodorous; and often presents an appearance so remarkably different, as not to be recognised even by the practised botanist. As the agency of light is requisite to the development of certain colours—so, many colours again are destroyed when its action is intense. This is shown in the rapid fading of coloured paper-hangings, silks and cottons, when exposed to strong sunlight, and in the discharge of vegetable colour by the process of bleaching. Again, we have chemical substances, which are to a certain extent characterized by the facility with which they enter into combination, or are decomposed, under the influence of light. For instance, a mixture of the two gases, chlorine and hydrogen, remains unaltered for any length of time in the dark; if exposed to the diffused daylight, the gases silently combine, but explode with considerable violence when a direct ray of sunshine falls upon the mixture. It is the same operation which is going on when chlorine water is found to be giving off a gaseous element: the solution of chlorine remains unaltered in the dark, but if exposed to sunshine, the chlorine enters into combination with the hydrogen of a portion of the water, and this eliminates a corresponding amount of oxygen in a gaseous form. In bright weather, the action of chlorine upon pyroxilic spirit is so violent, that the vessel requires to be carefully shaded to prevent the decomposition from proceeding with explosive violence; in gloomy weather, it is difficult to produce any action whatever. In sunlight, too, pure and colourless nitric acid (*aqua fortis*) speedily begins to send off oxygen gas, and to become yellowed from the nitrous acid which remains.* The fading of Prussian-blue patterns on cotton, is owing to a similar decomposition; the Prussian blue allows a portion of its base (*cyanogen*) to escape, and passes into a white compound with the portion of base which remains. The decomposition of the salts of silver, under the influence of the sunlight, is known to every one; the fact has become of interest to the arts, under the names of *photography*, and *photogenic drawing*. All that is necessary to practise photography is, to wash a sheet of paper with a very dilute solution of chloride, iodide, or bromide of potassium,† and then with a solution of nitrate of silver (*lunar caustic*); there is then formed in the substance of the paper, chloride, iodide, or bromide of silver, and this when in contact with organic matter, (as the substance of the paper,) is blackened by a very short exposure to moderate light. If an object which does not allow light to pass through it, be laid upon the paper thus prepared, and the whole be exposed to the solar beams for a few minutes, all those portions of the paper upon which the light strikes become black, whilst all below the object remain white; and in this way, the most delicate and complicated outlines of foliage and fibres may be obtained upon the paper, with a degree of accuracy inimitable by the hand. To render the drawing permanent, the unblackened silver must of course be removed. This is effected by washing the paper, after the picture is formed, with some substance capable of dissolving out the undecomposed salt of silver, as ammonia, hypo-sulphite of soda, or a strong solution of common culinary salt. This process depends upon the chemical agency of light, in decomposing the salt of silver, and in forming the black oxide of that metal: it is this oxide which gives the black colour to the ground

* The *nitric acid*, by giving out one atom of its oxygen, is changed into *nitrous acid*: the first, when pure, is colourless; the other is of a deep orange colour.

† These salts have no popular names: the first two may be procured from almost every chemist and apothecary; but the bromide, although preferable, cannot always be procured in a provincial town.

of the picture. The process of making pictures of external objects upon a prepared metallic plate, lately invented by Daguerre, and known technically as *Daguerreotype* — is analogous to photography, in so far as it depends upon the chemical agency of light, although the explanation can hardly be said as yet to have been supplied. Many other examples of the active influence of the same agent might be enumerated; but these will in general be better understood when we come to treat of the chemical history of individual substances.

It is not our intention at this stage, to examine the rival opinions entertained respecting the intimate nature of light: whether it be material particles darting from every material point of the light-giving body; or whether it is altogether to be ascribed to an undulation among the particles of an extremely subtle and elastic fluid diffused through all space. Difficulties, which we are not yet prepared to consider, attend both hypotheses, and render it necessary, in the first instance, to state the elements which go to make up the conditions of the question.

Among the first of those physical qualities of light which force themselves upon our attention, is its absence of weight; no one thinks of associating the idea of weight with a sunbeam, or of weighing the streams of light that flow from a candle. In this it resembles heat, and like that subtle agent too, it radiates from a source in every direction. The simplest considerations convince us that this is true: the flame of a candle is visible from all parts of a room, and a flash of lightning may be seen from all points around. The lighting up of the great expanse of heaven by the glorious sun—the fountain of light to our planetary system—is an illustration upon the grand scale of nature. The celestial luminary, ever shining, sends off his beams in all directions through all space, enlightening the earth and the other planets and their satellites in all their ever-changing positions. So far as our experience goes, all bodies which emit light, and which we therefore call *luminous* bodies, are composed of ponderable matter; and though light is itself imponderable, without ponderable material there can be no light. Every luminous body again may be regarded as composed of luminous points—each propagating its light around; but it is to the surface alone that we are indebted for the light that reaches the eye. The simple case of a red-hot ball of iron exemplifies what we mean: every particle of the iron is in a fit state to propagate light; but it is only the light of the external particles which renders the ball luminous—that of the internal matter is stifled in some way, and does not add to the luminosity of the mass. Light, moreover, passes through space with enormous velocity: that from the sun comes to the surface of our globe at the rate of about 192 thousand miles per second; and this motion is the same for light evolved from the most distinct fixed star, and the nearest self-luminous body. The proofs of this are derived from astronomy, and are as perfectly ascertained as any of the other facts of that magnificent science.*

Like every other emanation from a central point, the intensity of light diminishes as the square of the surface upon which it falls, increases. This law has already been pointed out for gravity, (at p. 36), and heat (at p. 108), and may be proved very satisfactorily by observing the different degrees of lumination received from a candle at different distances. It is likewise to be observed that the luminous emanation, when it passes through space free from all material substances, and through a medium of the same uniform nature and density, proceeds in straight lines. This law is rendered manifest by the very simplest experiments; or rather, indeed, so universally is the fact recognised, that it is made the basis of all that confidence which we repose in the phenomena of vision. When we are able to perceive an object through a long tube, the fact is proof enough to our minds that the tube is straight. It is in confidence of the truth of the same law that a sportsman takes his aim, and that a carpenter looks along the side of a plank to ascertain whether it be straight. In short, but for our confidence in the rectilinear passage of light, we could have no definite notion of direction, and there could hardly be such a thing as a shadow.

This leads us, however, to consider a little more strictly the sensation of seeing. Comparatively few bodies we know are self-luminous; by what is it then that bodies which give out no light of their own become visible? If we enter a room and make the window-shutters perfectly close, so that no light can find admittance, the eye turns upon an absolute blank; it perceives nothing. If then a small stream of the sun's light be admitted and made to fall upon any object, that object is rendered visible, and affects the eyes as if it were self-luminous. The fact proves that it has the power of scattering at least a portion of the light it receives—that is, of sending it off from its surface in straight lines; and some of these falling upon the organs of vision inform us of the presence of the luminated body. That the body is not perceived in consequence of any influence proceeding from the eye of the observer, as was held by some of the ancient philosophers, is evinced by the fact that before the light was admitted, we were unable to *see* the object. The effect varies also with the nature of the body upon which the light is received. If intercepted by a sheet of writing paper, which from its nature reflects much of the light which falls upon it, the apartment will be even well lighted: the reflected light from the intercepting surface, by falling upon other objects and by reflection from these again to others—like echo repeated many times before it dies among the perpendicular sides of a rocky cavern, waxing less and less—the effect grows fainter and the objects less distinct with every translation. If on the contrary, the light be received on black velvet, which hardly returns any light, the room will remain dark: and if again it be received on a polished surface, as on a mirror, nearly the whole of the light will be retained; but in one particular direction only: it will therefore be thrown upon some single object, and the effect will be according to the nature of that object, and very nearly as if the stream of light had reached it without reflection. It is similarly that all bodies upon the surface of the earth, and among these, the constituent particles of the mass of the atmosphere surrounding the earth, diffuse among themselves for a time, the light which they receive directly from the sun; "and by so doing, maintain everywhere that milder radiance so agreeable to the sight, which renders objects visible when the sun's direct ray does not fall upon them. But for this fact, indeed, all bodies shadowed from the sun, whether by intervening clouds, or by any other more opaque masses, would be perfectly black or dark—that is, totally invisible. And without an atmosphere, the sun would appear a round luminous mass in a perfectly black sky. On lofty mountain summits, where half the atmosphere is below the level, the direct rays of the sun are painfully intense, and the sky is of darkest blue." At great elevations, the blueness, indeed, merges into black, and almost totally disappears.

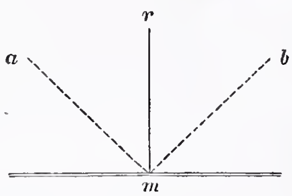
All bodies, then, which affect the eye with the sense of vision, have this quality either from their own light, or the light which they borrow from self-luminous bodies, and reflect again from their surfaces. Of this class of non-luminous bodies, there are many which totally intercept the passage of light; and thus produce *shadows* by obscuring the surfaces on which light would fall were they removed. Such bodies are called *opaque;* and the shadows which they produce, are in general bounded by lines which define the same figures as the sections of the intercepting bodies. Bodies again which allow light freely to traverse their substance, are termed *transparent* or *diaphanous*. But no solid substance with which we are acquainted possesses this property in a *perfect* degree; and perhaps the remark might be extended to all media whatever. Even air, the most diaphanous of all, intercepts a considerable portion of light; it has been estimated that of the horizontal sunbeams passing through about 200 miles of air, only about $\frac{1}{2000}$th part reaches us. Water too is very transparent, yet no sensible light can penetrate more than 700 feet deep into the sea; and it is found that a column of 7 feet of water is capable of intercepting one half of the light which enters it; and at a depth of 150 feet in the clearest sea, the light of the sun is not more intense than that of the moon. It is hardly necessary to observe, that the more nearly substances approach absolute transparency, the nearer are they to becoming invisible; it is by the interruptions of the passage of light, that bodies are brought

* By observations on the eclipses of Jupiter's satellites, it is found that light takes 16 minutes and 26 seconds to traverse the diameter of the earth's orbit, and consequently takes half that time to come to us from the sun. We know not at what distance from the earth the fixed stars are scattered; but we can be assured that they are not less than 200,000 times the distance of the sun from the earth, and accordingly, that light will take 200,000 times as long to reach us—that is, 3 years and 45 days; and it is no exaggeration to suppose that we can see stars which are situated some hundreds of millions of times farther distant, and whose light consequently takes a long series of ages to come to our globe; so that were they annihilated, we, the inhabitants of this earth, would for unnumbered years gain no intelligence of the catastrophe, but might continue to contemplate a spectacle which was but a deceitful illusion—an image without any reality.

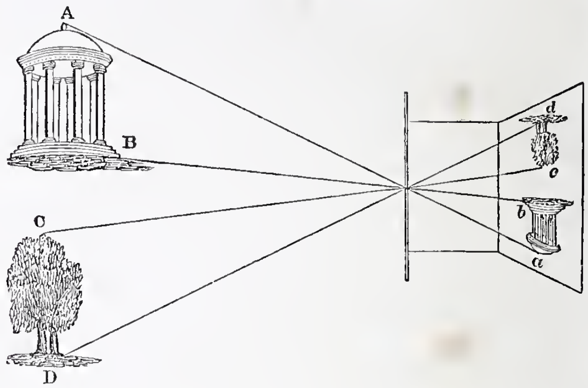
under the cognizance of our organs of vision, and not by the light which they transmit. It is for this reason that air is not visible; and that we are not sensible of the obstruction offered to light by a pure plate glass window.

As no substance possesses the property of transparency in a perfect degree, so on the other hand, there is reason to suppose that no body possesses the property of perfect reflection; but that light penetrates in an appreciable quantity into the surface of all bodies. This is well shown by very thin gold and silver leaf. If a portion of the former be placed over the only aperture by which the sun's light can enter an apartment, a quantity of bluish light passes through; if the screen be silver leaf, the light which permeates is purplish. In the two kinds of opacity—that of *blackness* when the light passes into the substance of the body and is absorbed; and that of whiteness, where the light is thrown off from the surface—we also find that portions of the light penetrate through when the materials are thin—as in black and white paper. In all these cases however, the passage of the light might perhaps be explained in connexion with the known porosity of the material. Particles, too, which have a thickness less than a certain definable quantity (the eight-millionth part of an inch), are known not to reflect light. Aqueous vapour ascending into the atmosphere does not affect the transparency of the air, because it is divided into particles too small to produce reflections; but when the particles unite into globules and vesicles, and form rain and fog, they reflect light, and become visible.

The primary law of reflection is, that the incident and reflected light are always in the same plane, and form equal angles with a perpendicular drawn to the surface at the point of incidence. It is generally thus enunciated—*the angle of reflection is equal to the angle of incidence.* That is, if $m$ be a reflecting surface—a mirror for instance—and $r$ a ray of light impinging upon it in a perpendicular direction from $r$ to $m$, it will be reflected in exactly the same direction from $m$ to $r$; but if the ray fall upon $m$ in the direction $a\ m$ it will be reflected in the direction $m\ b$; and at any equal distances from $m$, the points of $a\ m$ and $b\ m$ are equally distant from the perpendicular $r\ m$: this is equivalent to the mathematical expression, the angle of reflection $r\ m\ b$ is equal to the angle of incidence $r\ m\ a$. This is the same law which governs the collision of matter under the influence of mechanical force—whether that motion be of a solid, as an ivory ball projected against a marble slab, or of a fluid propagated by waves. In the case of light, the law may readily be proved by admitting a small sunbeam into a darkened apartment, and receiving it on a plane mirror: from this it will be thrown upon some other object, and taking a straight line from that object to the point of incidence $m$, we can verify the law by actual measurement. It may also be observed, that if we endeavour to verify the law with a non-metallic surface, we shall further find that the more obliquely the light is made to impinge upon that surface, the greater is the quantity reflected; but if the light be received upon a metallic surface, the converse of this holds true: the quantity of light reflected is greatest at small angles. A leaf of hot-pressed writing-paper may be used in the former case: it will afford a very perfect image of an object at a large angle. On the contrary, the image formed in a common looking-glass is brighter when formed by light falling upon it as nearly as possible in perpendicular lines. It must not be here objected that the surface of the mirror is non-metallic: it is not the glass that reflects the light which forms the image, but the mercury behind it. The glass acts chiefly as a transparent case, through which the rays find a ready passage: could the glass be altogether dispensed with, the mirror would be much more perfect. But the mercury is fluid, and it is only by making it into an amalgam with tinfoil and attaching it to the back of the plate of glass, that we can procure a surface of it sufficiently large and sufficiently convenient to serve the purpose of a looking-glass. Further, no other substance than an opaque one can be a mirror, and all such would be mirrors were their surfaces sufficiently smooth. But the surfaces of bodies in general are uneven, and divided into innumerable eminences and depressions, constituting in reality as many separate surfaces, disposed in all imaginable directions, so that from the inequality of the innumerable angles of incidence and reflection which are formed with respect to these surfaces, the light is scattered in every possible way, and no image is reflected. Were bodies, indeed, perfectly opaque, and their surfaces perfectly polished, our eye could give us no intimation of their existence; and had they no reflecting power at all, we would be in exactly the same difficulty. Had the moon, for instance, a polished surface like the speculum of an astronomer's telescope, it would be invisible; but the image of the sun which illumines it would reach us in its stead; and did it reflect none of the light that falls upon it, we could have no ocular knowledge of its existence.




But this leads us to consider a little more closely the formation of images and the sense of vision. We have said that objects are made visible by means of the light reflected from their surfaces—the question recurs as to the mode. It is not enough to say, that the rays proceeding from an object enter the eye: it is necessary to state, that the eye is provided with a screen—the *retina*—upon which the reflected rays fall, and form a picture of the object from which they proceed. To illustrate this, in a rude

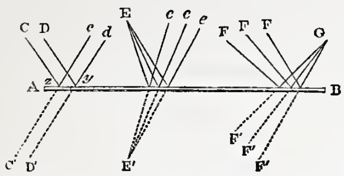



way,—suppose we provide a wooden box, blackened within, and make a very small hole in one end of it, and form the opposite end of oiled tissue paper, or the like; by presenting the end in which the hole is formed, towards a brightly illuminated object or landscape, an inverted picture of it is received upon the paper fixed at the opposite end, and presenting the very same lines as the object of which it is the image.* The picture is produced by the lines of light reflected from every point of the object, passing through the small aperture, and impinging upon the screen: some of these rays are of one colour, some of another, according to the nature of the surface from which they are reflected; and, moreover, some parts of the object send off more lines of light than other parts, and accordingly the lights and shades of the picture are preserved. It is thus that the pictures of objects are painted on the retina of the eye—the pupil of the eye through which the rays of light enter, answers to the small aperture in the box, and the image delineated on the retina is exactly similar to that depicted upon the paper. The only difference consists in the mechanism of the two sorts of apparatus—the delicate eye and our rude box—and in this respect the image we obtain is incomparably inferior in minuteness to that which our eye would receive from the same object. The delicacy of the picture formed in the eye when directed over an extended landscape is indeed minute beyond comprehension. Art would in vain attempt to paint so minute and distinct a miniature: the work is the work of Nature, whose hand is surer and whose pencil is more delicate than any which art can apply. The mechanism of the eye and its relations to light are, however, subjects for subsequent examination.

The formation of the image of an object by a plane mirror will not now be difficult to comprehend. The lines of light impinging upon the reflecting surface are reflected in sufficient quantity, and with sufficient regularity, to bring with them to the observer's eye, the exact representation of every part of the

* Such an instrument as that described, in a more perfect form, that is, fitted with a convex lens to transmit the light, constitutes the well-known optical instrument, the *Camera Obscura*, various forms of which will be described when we come to treat of optical apparatus.

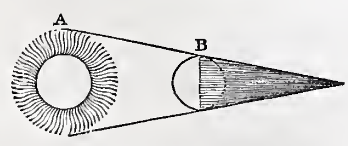
object from which they are primarily reflected. When the rays from an object are received upon a paper screen in a box, as already explained, they are not reflected in quantity and order, from the screen; they are intercepted, and form upon it a picture which may be regarded as the cross section of a mass of light, made up of single lines, each characteristic of the point of the object from which it proceeds; but when these lines fall upon what we may consider as a perfect reflector, all the lines that go to make up the picture are reflected and retain every one the same relative position and direction after reflection as before. To understand this, let A B be the surface of a plane polished mirror, and C and D two *parallel* rays incident upon its surface; the rays will be reflected in the directions *c* and *d* according to the law



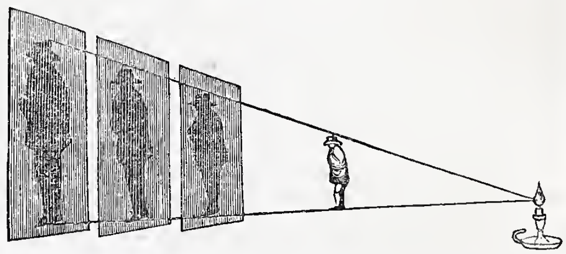

already enunciated. If the rays proceed from a point E and *diverge* as they proceed, after incidence they will continue their divergence in the directions *e e e*. Again, converging rays F F F will continue to converge after reflection towards the point G. In all these cases, as objects appear always to be situated in the direction of the rays which proceed from them, and eventually reach the eye, to spectators placed at *c d*, *e e e*, and G, the rays C D, E, and F F F will appear to have come from behind the mirror A B in the direction of the dotted lines C' D', E' and F' F' F'. The effect therefore of reflection is merely to throw the apparent origin of the rays to the opposite side of the mirror, and to invert the direction of the incident beams; for, taking the case of parallel rays, the ray D *y* being the uppermost, before reflection, passes in the direction of *y d* and becomes lower than *c x*, which represents the course of the reflected ray C *x*, and this before reflection was below D *y*. The same exact inversion of order holds in the other cases of diverging and converging light. And as all bodies evolve rays of light of their own colours, it therefore follows, that a spectator placed at *c d* will receive an exact image of an object situated at C D; he might also, were he not aware of the presence of the mirror, be deceived into the belief, that the object was situated at C' D',—that is as far behind A B as C D is before it. It is from being thus deceived, that a wild animal will attack its image in a glass; and the story of the dog which, while crossing a brook, quitted the piece of meat in its mouth to catch the tempting image in the water below, is too probable to be called a fable.

When we place a bright object, as a lighted candle, between two parallel mirrors, we perceive in each mirror an almost infinite series of images: the object, in the first instance, is reflected by each mirror, and the images thus formed are in their turn reflected, producing other images to be again reflected. At length the figures seem to become so remote, as to be lost in the distance. When the mirrors are inclined to each other at any angle, the images appear to lie in the circumference of a circle, of which the mirrors are the radii. This is, indeed, the principle of the Kaleidoscope, which at one time was expected to be of great service to the pattern drawer.

There cannot be any danger of confounding an image formed by reflection with one formed by the interception of light—nobody ever supposes that his likeness in a looking-glass and upon a wall are identical phenomena. Notwithstanding, however, that shadows are very familiar things and well understood, there are several things to be observed, in regard to their extent, of some interest. Although the shadow of a face on the wall be a correct profile, it may be very different in size from that of the original. This is indeed easily understood in ordinary cases. Supposing that the luminous body A is larger than the opaque body B, the shadow will gradually diminish in size till it terminates in a point; its cross section therefore, taken at any part, will be

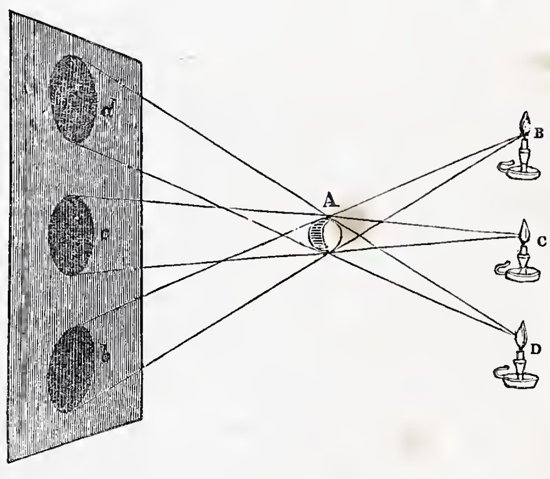



less than the body. This is true of the shadows of all the planets, and of the earth, because they are less than the sun which illuminates them. During night we are in the shadow of the earth, and when our moon is eclipsed—a phenomenon so awful in the early ages of the world—she simply passes through the long conical shadow which the earth casts beyond it. Again, when the luminous surface is smaller than the opaque body, the shadow is larger at any part of its cross section than the body itself. The shadow of a hand held up between a candle and the wall is gigantic, and a little pasteboard figure may throw a shadow as



large or larger than life. The size of a shadow varies, too, with the direction of the surface which receives it. Even when the light is thrown by the sun himself, we find that the shadows projected by objects on the earth are in proportion to the obliquity of the illuminating beams; at mid-summer noon they are short, but when the luminary has passed to the furthest point of his winter's tour, and projects his oblique rays upon us from the far south, our shadow upon a horizontal surface of snow has a dreary length. Morning and evening shadows are remarkably gigantic: a low wall will shadow from the sun a whole field, and a walking-stick becomes a rood in length.

It has sometimes been thought remarkable, that two lights should give two shadows from the same object. The circumstance, however, presents no difficulty. Shadow is not necessarily a total deprivation of light; nor is its apparent darkness in proportion to its real darkness, but to the intensity of the surrounding lights. An opaque object held between a candle and the wall casts a shadow of a certain intensity; but if another candle be placed in the same line from the shadow, the shadow will appear doubly dark, though in fact more light will be reaching it, and reaching the eye from it, than before: it becomes more dark, simply, by presenting a greater contrast. Further, if the candles be separated laterally, two shadows of the object will appear: for each candle makes the opaque body cast a different shadow. Three candles placed in different directions




similarly produce three shadows, and so of any number. If with our two candles we produce two shadows which coincide or overlap in one part, that part will be doubly dark, compared with the remainders. The most accurate mode of judging of the intensity of lights is by the darkness of the shadows which they throw, or better, by the distances at which they throw equally dark shadows of the same object. The eye judges readily of the comparative darkness of two shadows; but it does not readily determine when two white objects are made equally luminous.

# MATHEMATICS.

## CHAPTER VI.

### ARITHMETIC OF COMMON FRACTIONS.

If the principles laid down in the last chapter be well understood, the operations of this will present little difficulty. Those principles are, however, of little practical value in themselves: they derive their utility from the applications of them which we are about to consider; namely, the addition, subtraction, multiplication, and divisiou of fractions. We begin with the first of these operations.

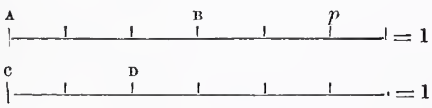
1. Suppose we have this question—what is the sum of *two-fifths* and *one-fifth?* The sort of units to be added are precisely the same: they are *fifths*, and their number is *two* and *one*, that is *three*. The answer to the question is therefore *three-fifths*. Now, the question and its answer written in symbols are

$$\frac{2}{5}+\frac{1}{5}=\frac{2+1}{5}=\frac{3}{5}$$

That is, *the sum of two fractions having a common denominator is found by taking the sum of the numerators, and writing under it the common denominator.*

But we have already shown, that fractions having any denominators, may be reduced to others having the same, or a common denominator; consequently, any two fractions may be added together by the preceding rule. Take an example:—

What is $\frac{1}{2}+\frac{1}{3}$? Here the fractions express different divisions of the primitive unit: $\frac{1}{2}$ is the expression for A B, and $\frac{1}{3}$ for C D;




but A B is equivalent to *three-sixths*, and C D to *two-sixths;* now *three-sixths* + *two-sixths*, are equivalent to *five-sixths* = A $p$. Or the whole written in symbols is

$$\frac{1}{2}+\frac{1}{3}=\frac{3}{6}+\frac{2}{6}=\frac{3+2}{6}=\frac{5}{6}$$

The same kind of reasoning may be applied to other cases, as the following:—

$$\frac{1}{2}+\frac{2}{7}=\frac{11}{14} \qquad \frac{3}{4}+\frac{1}{12}=\frac{5}{6} \qquad \frac{2}{3}+\frac{1}{5}=\frac{13}{15}$$

$$\frac{1}{2}+\frac{5}{6}=1\frac{1}{3} \qquad \frac{7}{12}+\frac{1}{6}=\frac{3}{4} \qquad \frac{8}{7}+\frac{9}{11}=1\frac{61}{77}$$

When it is required to find the sum of three or more fractions, the method of operation is strictly the same.

$$\text{Thus, } \frac{1}{2}+\frac{1}{3}+\frac{1}{4}=\frac{6}{12}+\frac{4}{12}+\frac{3}{12}=\frac{6+4+3}{12}=\frac{13}{12}=1\frac{1}{12}$$

$$\frac{1}{2}+\frac{2}{3}+\frac{3}{4}=1\frac{11}{12} \qquad \frac{1}{2}+\frac{1}{4}+\frac{1}{12}=\frac{5}{6}$$

$$\frac{1}{2}+\frac{3}{4}+\frac{4}{5}=2\frac{1}{20} \qquad \frac{7}{12}+\frac{1}{4}+\frac{1}{5}=1\frac{1}{30}$$

2. It frequently happens that the fractions accompany integers. In cases of this kind, we may operate upon the whole numbers and fractions separately. Take an example:—

What is $3\frac{2}{5}+2\frac{3}{4}$? The sum $3+2$ is 5, and the sum $\frac{2}{5}+\frac{3}{4}$ is $\frac{23}{20}=1\frac{3}{20}$: then $5+1\frac{3}{20}=6\frac{3}{20}$ is the answer sought. We might, therefore, have at once written

$$3\frac{2}{5}+2\frac{3}{4}=3+2+\frac{8}{20}+\frac{15}{20}=5+1\frac{3}{20}=6\frac{3}{20}$$

This is commonly the easiest mode of proceeding; but we may, should we think proper, reduce the mixed numbers to improper fractions, and proceed with the addition of the results as in the former cases.

$$\text{Thus, } 3\frac{2}{5}+2\frac{3}{4}=\frac{17}{5}+\frac{11}{4}=\frac{68+55}{20}=\frac{123}{20}=6\frac{3}{20}$$

$$\text{Similarly, } 1\frac{4}{5}+1\frac{5}{8}=1+1+\frac{32}{40}+\frac{25}{40}=2+\frac{32+25}{40}=3\frac{17}{40}$$

$$\text{or, } 1\frac{4}{5}+1\frac{5}{8}=\frac{9}{5}+\frac{13}{8}=\frac{72}{40}+\frac{65}{40}=\frac{137}{40}=3\frac{17}{40}$$

$$\text{Again, } 1\frac{1}{2}+2\frac{1}{3}+3\frac{1}{4}=1\frac{6}{12}+2\frac{4}{12}+3\frac{3}{12}=6\frac{13}{12}=7\frac{1}{12}$$

$$3\frac{1}{2}+4\frac{3}{4}=8\frac{1}{4} \qquad 11\frac{3}{4}+4\frac{2}{3}=12\frac{5}{12}$$

$$\frac{47}{4}+4+\frac{2}{3}+\frac{17}{6}+\frac{7}{12}+3\frac{1}{2}=23\frac{1}{2}$$

3. Subtraction is a mode of comparing quantities which are of the same kind. But fractions of the same species of unit, when made to have a common denominator, are greater or less tha each other according as their numerators are greater or less. Thus, $\frac{8}{9}$ is greater than $\frac{7}{9}$ by $\frac{1}{9}$, because both are made by dividing 1 into 9 equal parts, and the first has 8 of these parts, whereas the second has only 7.

$$\text{Therefore } \frac{8}{9}-\frac{7}{9}=\frac{8-7}{9}=\frac{1}{9}$$

and this is the answer to each of the questions—How much does $\frac{8}{9}$ *exceed* $\frac{7}{9}$? How much is $\frac{7}{9}$ *less* than $\frac{8}{9}$? If $\frac{7}{9}$ be subtracted from $\frac{8}{9}$ what quantity remains? And so on. The rule then for the subtraction of one fraction from another is very simple when they have both the same denominator; and it is only when they are placed in that condition that the subtraction can be effected. The rule may be expressed in full as follows:

*Reduce the fractions to a common denominator (if their given denominators be different); then take the difference of the numerators and place under it the common denominator; the new fraction thus formed, is the remainder sought.*

As examples of the application of this rule, it may be required to find the difference

$$\text{between } \frac{1}{2} \text{ and } \frac{1}{3}?\quad \frac{1}{2}-\frac{1}{3}=\frac{3}{6}-\frac{2}{6}=\frac{1}{6}$$

$$\text{“} \quad \frac{3}{4} \text{ and } \frac{2}{3}?\quad \frac{3}{4}-\frac{2}{3}=\frac{9}{12}-\frac{8}{12}=\frac{1}{12}$$

$$\text{“} \quad \frac{6}{7} \text{ and } \frac{4}{5}?\quad \frac{6}{7}-\frac{4}{5}=\frac{30}{35}-\frac{28}{35}=\frac{2}{35}$$

$$\text{“} \quad \frac{8}{9} \text{ and } \frac{7}{8}?\quad \frac{8}{9}-\frac{7}{8}=\frac{64}{72}-\frac{63}{72}=\frac{1}{72}$$

4. When whole numbers and fractions are conjoined, they may b operated upon either separately, or by reducing them to improper fractions, as in the case of addition; but it will be found in practice, that as the first mode is the readiest in addition, the latter is the most convenient in subtraction.

$$\text{Thus, } 2\frac{1}{2}-1\frac{2}{3}=\frac{5}{2}-\frac{5}{3}=\frac{15-10}{6}=\frac{5}{6}$$

By proceeding in this instance to reduce the $\frac{1}{2}$ and $\frac{2}{3}$ to a common denominator, we arrive at a subtraction $2\frac{3}{6}-1\frac{4}{6}$ which is an impossible expression as respects the fractions. This, however, may be remedied by taking a unit of the 2; and writing it $\frac{6}{6}$; then adding this to the $\frac{3}{6}$ we get $\frac{9}{6}$; which makes our expression possible in all its parts: it is

$$1\frac{9}{6}-1\frac{4}{6}=\frac{5}{6} \text{ as before.}$$

As this sort of difficulty will reappear in practice in as many instances as it will not happen, it may be advisable for the student, in the meantime, to adopt the former mode in preference. The following examples may be verified.

$$3\frac{1}{5}-2\frac{7}{8}=\frac{16}{5}-\frac{23}{8}=\frac{128-115}{40}=\frac{13}{40}$$

$$13\frac{1}{2}-7\frac{3}{4}=5\frac{3}{4} \qquad 12\frac{3}{4}-10\frac{13}{16}=1\frac{15}{16}$$

The following are examples of cases which very frequently occur in practice. The readiest mode of proceeding is this: find the sum of all the *additive* terms, and the sum of all the *subtractive*, and find the difference of the results.* One example will make this plain.

What is $\frac{1}{2}-\frac{1}{3}+\frac{1}{4}-\frac{1}{5}+\frac{1}{6}$? Here the two sorts of quantities are

* By additive terms are meant those which have *no sign* or the sign + prefixed to them; the subtractive terms again are thus preceded by the sign of subtraction.

$$\textit{Additive}\ \tfrac{1}{2}+\tfrac{1}{4}+\tfrac{1}{6}=\tfrac{6}{12}+\tfrac{3}{12}+\tfrac{2}{12}=\tfrac{11}{12}$$

$$\textit{Subtractive}\ \tfrac{1}{3}+\tfrac{1}{5}=\tfrac{5}{15}+\tfrac{3}{15}=\tfrac{8}{15}$$

$$\text{Then, } \tfrac{11}{12}-\tfrac{8}{15}=\tfrac{55}{60}-\tfrac{32}{60}=\tfrac{23}{60}$$

$$\text{Similarly, } \tfrac{1}{2}+\tfrac{1}{3}+\tfrac{1}{6}-\tfrac{1}{8}-\tfrac{1}{4}=\tfrac{5}{8}$$

$$2-\tfrac{1}{7}+\tfrac{12}{13}=2\tfrac{71}{91} \qquad 11\tfrac{2}{3}+8\,\tfrac{7}{9}-9\tfrac{19}{22}=10\tfrac{115}{196}$$

$$1-\tfrac{1}{2}+\tfrac{2}{3}+\tfrac{3}{4}+\tfrac{4}{5}+\tfrac{5}{6}=3\tfrac{11}{20}$$

5. Suppose it required to multiply $\frac{3}{4}$ by 5. This by the meaning which we have hitherto attached to multiplication, is to take $\frac{3}{4}$ as many times as there are units in 5, that is five times. The result is therefore

$$\tfrac{3}{4}+\tfrac{3}{4}+\tfrac{3}{4}+\tfrac{3}{4}+\tfrac{3}{4}=\tfrac{15}{4}=3\tfrac{3}{4}$$

But this is exactly the same as if we had multiplied the numerator 3 by 5, and placed the denominator under the product; or

$$\tfrac{3}{4}\times 5=\tfrac{3\times 5}{4}=\tfrac{15}{4}=3\tfrac{3}{4} \text{ as before.}$$

Again, suppose it required to multiply $\frac{3}{20}$ by 5. Proceeding as before we get

$$\tfrac{3}{20}+\tfrac{3}{20}+\tfrac{3}{20}+\tfrac{3}{20}+\tfrac{3}{20}=\tfrac{15}{20}=\tfrac{3}{4}$$

But this last result is the same as if we had divided the denominator of the given fraction by the given multiplier, and placed the numerator over the quotient; or

$$\tfrac{3}{20}\times 5=\tfrac{3}{20\div 5}=\tfrac{3}{4} \text{ as before.}$$

From these two examples, it then appears that a fraction is multiplied by a whole number either by multiplying its numerator, or dividing its denominator by that number. The first of these methods is however the most general, since we can always multiply; the second can only be *conveniently* applied when the denominator of the fraction is divisible by the multiplier given. The following cases may be verified :—

$$\tfrac{6}{11}\times 5=\tfrac{6\times 6}{11}=2\tfrac{8}{11} \qquad \tfrac{11}{18}\times 3=1\tfrac{5}{6} \qquad \tfrac{8}{19}\times 38=16$$

$$\tfrac{6}{35}\times 7=\tfrac{6}{35\div 7}=1\tfrac{1}{5} \qquad \tfrac{9}{25}\times 5=1\tfrac{4}{5} \qquad \tfrac{5}{73}\times 9=\tfrac{5}{7}$$

6. To divide a fraction by a whole number, is equally simple : take this question.

What is $\frac{3}{4}$ divided by 6? We are required to perform an operation upon $\frac{3}{4}$ which is exactly the inverse of multiplying it by 6 : now to find $\frac{3}{4}\times 6$ is to write

$$\frac{3\times 6}{4} \text{ or } \frac{3}{4\div 6}$$

we may therefore conclude, that to find $\frac{3}{4}\div 6$ is to write

$$\frac{3\div 6}{4} \text{ or } \frac{3}{4\times 6}$$

These forms of expression are both correct, for

$$\tfrac{3\div 6}{4}\times 6=\tfrac{18\div 6}{4}=\tfrac{3}{4} \text{ and } \tfrac{3}{4\times 6}\times 6=\tfrac{3\times 6}{4\times 6}=\tfrac{3}{4}$$

and the proof that a quotient is correct, consists in its reproducing the dividend when multiplied by the divisor.

The rule therefore for the division of a fraction by an integer is this : *Multiply the denominator or divide the numerator by the whole number.*

$$\text{Thus } \tfrac{8}{9}\div 4=\tfrac{2}{9} \qquad \tfrac{8}{7}\div 7=\tfrac{8}{49} \qquad \tfrac{55}{71}\div 11=\tfrac{5}{71}$$

7. The converse of (Art. 5.) is the multiplication of a whole number by a fraction. In reality, the two operations coincide, in so far as their results are the same ; but the principle that A multiplied by B, is the same as B multiplied by A, although very clear when A and B are whole numbers, is not so immediately apprehended when applied to fractions. Thus no one hesitates to admit that $\frac{2}{3}$ multiplied by 6 is $\frac{12}{3}$ or 4 ; but it requires a little consideration to satisfy the mind for the first time, that 6 multiplied by $\frac{2}{3}$ is also 4. It requires in fact an extension of the meaning which we have been attaching to the word *multiplication.* This, as we have remarked above, is defined to be the taking a number (it may be whole or fractional) as often as the number which we call our multiplier contains 1. But all proper fractions are *less* than 1 ; multiplication therefore by any such fraction appears by the definition an absurdity. The difficulty, however, lies in our mode of expression—in its want of comprehensiveness. Instead of our limiting expression—*take* A (*the multiplicand*) *as often as there are units in* B (*the multiplier*) ; let us put the following :—*perform the same operation upon* A *that is performed upon* 1 *in order to form* B ; this comprehends all that is meant by the former, and moreover, does not restrict us to addition ; for B may be a fraction formed by dividing 1 into parts, and taking some of those parts. To show how this applies, let us give A and B particular values ; that is, take this question—

What is 18 multiplied by $\frac{5}{6}$?

Whatever is done with 1 in order to make $\frac{5}{6}$, is to be done with 18 ; but to make $\frac{5}{6}$ we divide 1 into 6 parts, and take 5 of them ; therefore to make $18\times\frac{5}{6}$, we must also divide 18 into 6 parts, and take 5 of them. Now 18 distributed into 6 parts is

$$3+3+3+3+3+3$$

and 5 of these parts make 15. This result is likewise the product of $\frac{5}{6}$ by 18, and hence we conclude that

$$18\times\tfrac{5}{6}=\tfrac{5}{6}\times 18=\tfrac{18\times 5}{6}$$

The notion then which is to be formed is this :—that any number multiplied by another, must give a product bearing the same relation to the number which is to be multiplied that the multiplier bears to 1. We shall always find the first meaning of the word *multiplication* included in this enlarged meaning : it applies to all cases whether the multiplier be greater or less than 1. To show its application where the multiplier and multiplicand are both fractions, let us take the question—

8. What is $\frac{3}{4}$ multiplied by $\frac{5}{7}$? Whatever is done with 1 to make $\frac{5}{7}$ is to be done with $\frac{3}{4}$; we must therefore divide $\frac{3}{4}$ into 7 equal parts, and take 5 of them. Now putting for $\frac{3}{4}$ its equivalent $\frac{3\times 7}{4\times 7}$ that is $\frac{21}{28}$ ; if $\frac{21}{28}$ be divided into 7 equal parts, each of them is $\frac{3}{28}$, and if 5 of these parts be taken, the result is $\frac{3\times 5}{28}=\frac{15}{28}$: therefore $\frac{3}{4}$ multiplied by $\frac{5}{7}$ is $\frac{15}{28}$, and the same reasoning may be applied to any other fractions. But if

$$\tfrac{3}{4}\times\tfrac{5}{7}=\tfrac{15}{28} \text{ which is } =\tfrac{3\times 5}{4\times 7}$$

then is the product of two fractions found by multiplying together the two numerators for the numerator, and the two denominators for the denominator ; and this furnishes the rule for the multiplication of fractions. It furnishes, moreover, a *general* rule : for if this product $\frac{15}{28}$ is to be multiplied by a third fraction, for instance $\frac{3}{8}$, the result is found by the same kind of reasoning to be $\frac{45}{224}$ that is $\frac{3\times 5\times 3}{4\times 7\times 8}$. And so on of any greater number of fractions. Hence we conclude that the general rule for multiplying any number of fractions together is this :—

*Multiply all the numerators together for the numerator of the product, and all the denominators together for its denominator.*

$$\text{Examples} \qquad \tfrac{2}{7}\times\tfrac{5}{9}=\tfrac{10}{63} \qquad \tfrac{5}{3}\times\tfrac{11}{12}=\tfrac{55}{36}$$

$$\tfrac{3}{2}\times\tfrac{5}{7}\times\tfrac{3}{11}=\tfrac{45}{154} \qquad \tfrac{3}{16}\times\tfrac{7}{20}\times\tfrac{3}{11}=\tfrac{63}{3520}$$

There is another mode which the student may practise, in order thoroughly to satisfy himself of the truth of the rule for the multiplication of one fraction by another. It is this—supposing it required to find $\frac{8}{9}\times\frac{5}{7}$.

$$\text{Then } \frac{8}{9} \times 5 = \frac{40}{9}\text{ ; and}$$

$$\frac{8}{9} \times \frac{5}{7} = \frac{40}{9} \div 7 = \frac{40}{63}\text{ ; therefore}$$

$$\frac{8}{9} \times \frac{5}{7} = \frac{40}{63}\text{ as by the foregoing rule.}$$

Any other cases may be treated in the same way.

9. Suppose it required to multiply together $\frac{10}{21}$ and $\frac{7}{8}$. The product may be written thus :

$$\frac{10 \times 7}{21 \times 8} \text{ that is } \frac{70}{168} \text{ which by reduction is } \frac{5}{12}.$$

But this result might have been obtained directly by observing that 10 and 8 are both measured by 2, and that 7 and 21 are measured by 7 ; and that in fact

$$\frac{10 \times 7}{21 \times 8} \text{ is equivalent to } \frac{5 \times 2 \times 7}{3 \times 7 \times 2 \times 4}$$

and dividing both the numerator and denominator by $2 \times 7$, this last is reduced to $\frac{5}{3 \times 4} = \frac{5}{12}$. We therefore conclude that when factors are common to a numerator and denominator, they may be expunged before making the multiplication.

$$\text{Thus} \quad \frac{16}{24} \times \frac{35}{21} = \frac{8' \times 2}{8' \times 3} \times \frac{7' \times 5}{7' \times 3} = \frac{2}{3} \times \frac{5}{3} = \frac{10}{9}$$

$$\frac{2}{3} \times \frac{3}{4} \times \frac{5}{6} \times \frac{4}{5} = \frac{2 \times 3' \times 5' \times 4'}{3' \times 4' \times 6 \times 5'} = \frac{2}{6} = \frac{1}{3}$$

10. The word *of* is frequently used instead of the sign of multiplication between two fractions : when this is the case, the expression is sometimes called a compound fraction. For instance, $\frac{2}{3}$ *of* $\frac{3}{4}$ is a compound fraction, but $\frac{2}{3} \times \frac{3}{4}$ which means the same thing, is called a product : but the arithmetic of the two forms of expression is strictly the same. It may likewise be observed, that our rule for multiplying fractions together applies equally to whole numbers, since any whole number may be regarded as a fraction whose denominator is 1. When the quantities to be multiplied together happen to be made up of integers and fractions, the most convenient mode of proceeding is, to convert them into improper fractions, and operate upon the results as directed in the rule (Art. 8).

$$\text{Thus} \quad 3\tfrac{2}{9} \times 7\tfrac{1}{3} = \frac{29}{9} \times \frac{22}{3} = \frac{638}{27} = 23\tfrac{17}{27}$$

$$45\tfrac{3}{4} \times 17\tfrac{2}{3} = \frac{183}{4} \times \frac{53}{4} = \frac{9699}{12} = 808\tfrac{1}{4}$$

11. The extension of our term in multiplication requires that we make a similar extension in the case of division, where the quantity given as a divisor is a fraction. The principle upon which the extension depends can however be made very obvious. Supposing that we want to know the length of a plank, and find that a rule of 2 feet in length measures it at 5 times : we thereby know that a rule of 1 foot would measure it at 10 times ; and that $\frac{1}{2}$ foot rule would require to be applied 20 times to tell its length. From this then it is obvious, that the smaller the measure we apply, the more times is it contained in the given length. Supposing now that we know that the length of our plank is 10 feet, and wish to ascertain into how many lengths of $\frac{2}{3}$ of a foot it may be cut, we have then this question :—

How many times does 10 contain $\frac{1}{3}$ ?

Now $\frac{2}{3}$ is twice $\frac{1}{3}$, the length 10 must therefore contain $\frac{2}{3}$ just half the number of times that it contains $\frac{1}{3}$ ; again, every unit in 10 contains $\frac{1}{3}$ *three times;* 10 therefore contains $\frac{1}{3}$ *thirty times*, and consequently contains $\frac{2}{3}$ half as often or *fifteen times*. This reasoning put into symbolical language is this :—

$$1 \div \frac{1}{3} = 3$$

$$\text{Therefore } 10 \div \frac{1}{3} = 3 \times 10 = 30$$

$$\text{and hence } 10 \div \frac{2}{3} = \frac{1}{2} \text{ of } 30 = 15$$

Take another example :—Divide 7 by $\frac{8}{9}$.

$$\text{Because } 1 \div \frac{1}{9} = 9\text{ ;}$$

$$\text{therefore } 7 \div \frac{1}{9} = 7 \times 9 = 63\text{ ;}$$

$$\text{and therefore } 7 \div \frac{8}{9} = \frac{1}{8} \text{ of } 63 = \frac{63}{8} = 7\tfrac{7}{8}.$$

But from this last it would appear that

$$7 \div \frac{8}{9} \text{ is equivalent to } 7 \times \frac{9}{8}.$$

for both give $\frac{63}{8}$. We hence conclude that to *divide* by a fraction is the same as to *multiply* by that fraction inverted. This may be proved with the following cases :—

$$5 \div \frac{2}{3} = 5 \times \frac{3}{2} \qquad 12 \div \frac{7}{11} = 12 \times \frac{11}{7}.$$

12. The principle remains the same whatever the question may be. To show that it is applicable when the dividend is also a fraction, let it be required to divide $\frac{3}{4}$ by $\frac{5}{7}$.

$$\text{Because } 1 \div \frac{1}{7} = 7$$

$$\text{therefore } \frac{1}{4} \div \frac{1}{7} = \frac{1}{4} \text{ of } 7 = \frac{7}{4}$$

$$\text{and } \frac{3}{4} \div \frac{1}{7} = 3 \times \frac{7}{4} = \frac{21}{4}$$

$$\text{and therefore } \frac{3}{4} \div \frac{5}{7} = \frac{1}{5} \text{ of } \frac{21}{4} = \frac{21}{20}$$

$$\text{But } \frac{21}{20} = \frac{3 \times 7}{4 \times 5} = \frac{3}{4} \times \frac{7}{5} = \frac{3}{4} \div \frac{5}{7}$$

We may view the question differently. According to the nature of division, the *divisor* multiplied into the *quotient* must give back the *dividend :*

$$\text{that is } \frac{5}{7} \times \textit{quotient} = \frac{3}{4}$$

Now these equal quantities when multiplied by the same quantity must still be equal ; let them therefore be both multiplied by $\frac{7}{5}$, that is, let

$$\frac{7}{5} \times \frac{5}{7} \times \textit{quotient} = \frac{3}{4} \times \frac{7}{5}$$

But $\frac{7}{5} \times \frac{5}{7} = \frac{35}{35} = 1$ ; and any quantity multiplied by 1 is not altered in magnitude ; therefore the expression above is reducible to

$$\textit{quotient} = \frac{3}{4} \times \frac{7}{5} = \frac{21}{20}$$

and this is the same result that we arrived at before. It must be admitted, however, that a proof conducted in this manner is rarely satisfactory to the beginner ; and as it is for such that we write, we may add the following which is more direct :—

Let the given fractions $\frac{3}{4}$ and $\frac{5}{7}$ be reduced to a common denominator ; they then become $\frac{21}{28}$ and $\frac{20}{28}$. Now as these fractions express the same kind of subordinate units, it is clear that $\frac{21}{28}$ divided by $\frac{20}{28}$ must give the same result as 21 divided by 20 ; that is, $\frac{21}{20}$ which is equivalent to $\frac{3 \times 7}{4 \times 5}$.

13. From all these ways then of considering the problem, we arrive at this rule :—

*To divide by a fraction, invert its terms and multiply.*

The following are examples of the application of this rule :—

$$\frac{1}{3} \div \frac{2}{5} = \frac{1}{3} \times \frac{5}{2} = \frac{5}{6} \quad \Big| \quad \frac{3}{7} \div \frac{5}{8} = \frac{24}{35}$$

$$\frac{3}{8} \div \frac{4}{3} = \frac{3}{8} \times \frac{3}{4} = \frac{9}{32} \quad \Big| \quad \frac{15}{19} \div \frac{8}{11} = \frac{165}{152}$$

14. When the numerators and denominators have any common factors, the work may be simplified by striking them out before performing the division.

$$\text{Thus, } \frac{27}{35} \div \frac{18}{55} = \frac{9' \times 3}{5' \times 7} \div \frac{9' \times 2}{5' \times 11} = \frac{3}{7} \div \frac{2}{11} = \frac{33}{14}$$

15. When integers are joined to the fractions, the easiest mode of proceeding is, transform the mixed quantities into improper fractions, and then proceed as directed in the rule.

$$\text{Thus, } 2\tfrac{1}{3} \div 4\tfrac{3}{4} = \frac{7}{3} \div \frac{19}{4} = \frac{7}{3} \times \frac{4}{19} = \frac{28}{57}$$

16. The preceding are the operations which the student will

frequently find himself called upon to perform in fractional arithmetic. They are usually supposed to present extraordinary difficulties, and it must be admitted, that to a person who has never studied the *rationale* of the rules employed, they are not over intelligible. Everything depends upon having clear and precise ideas of the nature of fractional quantities, and of the relations which the operations to be performed upon them bear to the analogous processes performed upon whole numbers. The following questions will test the progress which the student has made up to this point.

Find the sum, difference, and product of $\frac{3}{4}$ and $\frac{3}{5}$. *Ans.* $\frac{27}{20}$; $\frac{3}{20}$; $\frac{9}{20}$.

Divide the sum of $\frac{1}{2}$ and $\frac{1}{3}$ by the sum of $\frac{1}{3}$ and $\frac{1}{4}$. *Ans.* $\frac{10}{7}$.

Find $\frac{1}{2}$ of $\frac{1}{3}$ of $\frac{1}{4}$ of $\frac{1}{5}$, and multiply the result by 10. *Ans.* $\frac{1}{12}$.

Multiply $\frac{1}{2}$ of $\frac{2}{3}$ by $\frac{3}{4}$ of $\frac{4}{5}$, and divide the result by $1\frac{1}{4}$. *Ans.* $\frac{4}{25}$.

Add together $2\frac{1}{2}$ and $\frac{1}{6}$, and divide the result by $3\frac{1}{2}-\frac{1}{8}$. *Ans.* $\frac{64}{81}$.

Divide $\frac{7}{6}$ of $\frac{1}{2}$ of $\frac{3}{10}$ by $\frac{6}{11}$ of $\frac{7}{8}$ multiplied by $4\frac{1}{2}$. *Ans.* $\frac{11}{135}$.

Divide the product of $\frac{21}{16}$ and $\frac{10}{7}$ by $\frac{1}{8}$ of 15. *Ans.* 1.

A's share was $\frac{27}{38}$, of which he sold $\frac{3}{4}$, how much remained? *Ans.* $\frac{27}{152}$.

A man performed a journey in $6\frac{13}{18}$ hours; what part of the journey did he perform in 1 hour? *Ans.* $\frac{18}{121}$.

A gave B $\frac{3}{4}$ of his share, and B gave C $\frac{4}{5}$ of what he got; how much of A's share did C get? *Ans.* $\frac{3}{5}$.

The line A is equal to $\frac{4}{5}$ of the line B, and the line B is equal to $\frac{3}{4}$ of the line C; what part is the line A of the line C? *Ans.* $\frac{3}{5}$.

# GEOLOGY.

## CHAPTER VIII.

### EARTHQUAKES.

Those who live in countries where the earthquake and volcano are unknown, can form no adequate idea of their effects unless they study the phenomena produced, in remote geological epochs, by similar causes, in the structure of volcanic rocks, the existence of trap dykes, the dislocation of strata, and the undulations which the stratified beds often exhibit. In examining these, we have the most decided proof that our own land, now so stable, was once subject to dreadful convulsions, and presented phenomena strictly analogous to those recorded as occurring in countries situated near the foci of active volcanoes. Exceedingly little is known as to the real cause of earthquakes. There can be no doubt, however, that they spring from agencies similar to those which produce the volcano—namely, the existence of heat, and the explosion of gaseous bodies in the subterranean regions. Whether that heat, or these explosions, are the result of chemical changes, effected by new combinations, or are caused by the existence of an incandescent mass of molten matter underneath the solid frame-work of the earth, it is, perhaps, impossible to determine. We have already alluded to the fact, that the temperature of the earth increases in proportion to descent from the surface, and in such degree as to warrant the opinion that the central parts are hotter than melted iron. But we naturally ask, if such be the case, why is it that one part of the crust of the globe is affected with volcanic action, while another remains in a quiescent state? Why is it that a country like Scotland, once the scene of the most tremendous agitation and volcanic convulsion, is now comparatively at rest, while the recent cones of Etna and Vesuvius vomit their lava and their smoke, and the adjacent lands everywhere exhibit the devastations of the earthquake? These questions, we confess, are ill to solve, upon the supposition of central heat, unless we can suppose that the direction of its active forces to other parts causes them to cease in regions formerly active; but, in seeking for the causes of disturbance, we are not necessarily confined to the consideration of the evolution of heat from the central mass. We know that heat is evolved when two bodies, having a strong affinity for each other, suddenly unite; and "that chemical changes develop electricity, which, in its turn, becomes a powerful disturbing cause."

Thermo-electricity may be produced from difference of temperature; for wherever masses of rock of great horizontal extent, and of considerable depth, occur, which are at one point in a state of fusion, (or beneath some active volcano,) at another red hot, and at a third comparatively cold, strong thermo-electric action may be excited.

"During volcanic eruptions," says Mr Lyell, "vivid lightnings are almost invariably seen in the clouds of vapour which ascend from the crater, and as there are always one or more eruptions going on in some part or other of the globe, we are here presented with another perpetual source of derangement. How far subterranean electric currents may possess the decomposing power of the voltaic pile, is a question for those alone who are farthest advanced in the career of discovery in a rapidly progressive science; but such a power would at once supply us with a never-failing source of chemical action from which volcanic heat might be discovered."

It is well known to chemists that the metallization of oxides, the most difficult to reduce, may be effected by hydrogen, when brought in contact with them at a red heat; and it is more than probable, continues Mr Lyell, "that the production of potassium itself, in the common gun-barrel process, is due to the nascent hydrogen derived from the water which the hydrated oxide contains. It has never been disputed that intense heat might be produced by the occasional contact of water with the metallic bases, and it is quite certain that, during the process of saturation, vast volumes of hydrogen must be evolved: the hydrogen thus generated might permeate the crust of the earth in different directions, and be stored up for ages in fissures and caverns, sometimes in a liquid form under the necessary pressure. Whenever, at any subsequent period, in consequence of the changes effected by earthquakes in the shell of the earth, this gas happened to come in contact with metallic oxides at a high temperature, the reduction of the latter would be the necessary result." From these speculations, it will readily appear that the most eminent of our geologists have arrived at no determinate conclusion as to the real causes of volcanic phenomena; but, withal, it appears that we must seek for it in chemical and thermo-electrical action, excited by heat radiating from the central mass of the earth. The heat, from whatever source derived, must be intense, which is not only capable of melting rocks and converting them into fiery lava, but able to reduce solid rock into gas, which, struggling for vent, finds its way through the volcanic crater, with force sufficient, in many instances, to project stones of enormous size and weight through the atmosphere to the distance of many miles, or which, if not finding that mode of escape, communicates to the earth the tremulous shock of the earthquake; rending, when violent, the solid earth, elevating tracts of country, changing the currents of rivers, destroying towns, and burying their inhabitants in a common grave.

Nothing, perhaps, produces a greater sensation on the mind of man than one of these shocks. The convulsive heavings of the earth, the tottering of towers and other buildings, the crashing of timber, and the falling of tiles and houses, amidst the ghastly looks of terrified multitudes clinging to posts, or laying themselves prostrate, or on their knees, and imploring the mercy of Heaven—is a scene which none but those who have witnessed it can well conceive. The terror is communicated to bird and beast: the one standing with their legs spread out, and trembling with dread; and the other, flying wildly about in all directions. Previous to an earthquake, or after it, there is generally considerable irregularity in the weather. Sudden gusts of wind, succeeded by dead calms—a hazy atmosphere, and a sun of a deep red colour—sulphurous vapours issuing from the earth—dizziness of head, and a sensation like that of sea-sickness, are, also, usual concomitants of these frightful visitations.

To give anything like a detail of the disastrous occurrences

which have attended earthquakes, would require a volume. We propose, therefore, to confine ourselves to such as have produced those changes which render the earthquake interesting to the geologist, beyond the mere excitement its disasters occasion.

An earthquake is mentioned as having occurred in the year 365, which was felt through the whole of the Roman empire, that caused the sea to retire to great distances, in many places, from the coast, while in other localities it converted whole provinces into sea.

In the 6th century, the island of Coos was almost wholly sunk under the ocean by an earthquake.

In the following century, we are told by Nauclerus, that during an earthquake in Mesopotamia, the earth was cleft asunder for nearly two miles, and that several towns were removed from the hills into the adjoining plains.

Plantina mentions an earthquake which occurred in the beginning of the 9th century, which threw down St Paul's Cathedral at Rome. It was felt throughout the greater part of Europe. It destroyed many towns, and even removed mountains.

In 1618, Pleurs, a town in Rhetia, was completely overwhelmed by the fall of a hill, and 1500 people buried.

In 1792, a tremendous earthquake occurred in Sicily, during which Catania, and several other towns, were completely engulphed, and 73,000 people killed.

An earthquake occurred in Murcia, in Spain, in 1829, which rent the earth with innumerable crevices, from 4 to 5 inches broad, and lowered the position of several villages below their former level. Near the sea small circular apertures were formed, which vomited black mud, salt water, and marine shells; and in other places, fine yellowish-green sand was thrown up in jets.

On the 19th of November, 1822, the coast of Chili was raised from 3 to 4 feet above its former level, for the distance of 100 miles. "In order to give some idea of the enormous amount of change which this single convulsion may have occasioned," says Mr Lyell, "let us assume that the extent of country moved was correctly estimated at 100,000 square miles—an extent just equal to half the area of France, or about five-sixths of Great Britain and Ireland. If we suppose the elevation to have been only three feet on an average, it will be seen that the mass of rock added to the continent of America by the movement, or, in other words, the mass previously below the level of the sea, and, after the shocks, permanently above it, must have contained fifty-seven cubic miles in bulk; which would be sufficient to form a conical mountain two miles high, (or about as high as Etna,) with a circumference at the base of nearly thirty-three miles. We may take the mean specific gravity of the rock at 2·655—a fair average, and a convenient one in such computations, because at such a rate a cubic yard weighs two tons. Then assuming the great pyramid of Egypt, if solid, to weigh, in accordance with an estimate before given, six millions of tons, we may state the rock added to the continent by the Chilian earthquake to have more than equalled 100,000 pyramids. But it must be borne in mind that the weight of rock here alluded to, constituted but an insignificant part of the whole amount which the volcanic force had to overcome. The whole thickness of rocks, between the surface of Chili and the subterrannean foci of volcanic action, may be many miles or leagues deep—say that the thickness was only 2 miles, even then the mass which changed place and rose three feet must have been 200,000 cubic miles in volume. It may be useful," Mr Lyell continues, "to consider these results with others already obtained from a different source, and to compare the working of two antagonist forces—the leveling power of running water, and the expansive energy of subterranean heat. How long, it may be asked, would the Ganges require, according to data before explained, to transport to the sea a quantity of solid matter equal to that added to the land by the Chilian earthquake?" He then proceeds to show that the mud discharged in one year by the Ganges, equalled the weight of sixty pyramids. In which case, it would require seventeen centuries and a half before the river could bear down from the continent into the sea, a mass equal to that gained by the Chilian earthquake.

During an earthquake which occurred in India, in 1819, the estuary of the Indus, which before the shock was fordable at a place called Luckput, being only about a foot and a half deep at ebb tide, and at flood tide never more than six feet, was deepened at that place to 18 feet at low water. At the same time, the fort and village of Sindree were overflowed, so that the top of the houses only rose above the water. Immediately after the shock, at a distance of 5½ miles from the village, a long elevated mound rose in a place where there was previously a low and perfectly level plain. The uplifted land, indicated by this mound, extended for upwards of 50 miles in length, and in breadth, in some parts, to 16 miles. In 1828, Captain Burns visited the ruins of the submerged village in a boat, when a single remaining tower was seen in the midst of a wide expanse of sea. The tops of the ruined houses still stood a foot or two above the level of the water; upon one of which the captain placed himself, and, looking round, could see nothing but water except in one direction, where a blue streak of land indicated the existence of the recently elevated land, called "Ulla Kaud," or the "Mound of God." "These scenes present," says Mr Lyell, "to the imagination a lively picture of the revolutions now in progress in the earth—a waste of water where a few years before all was land, and the only land visible consisting of ground uplifted by a recent earthquake."

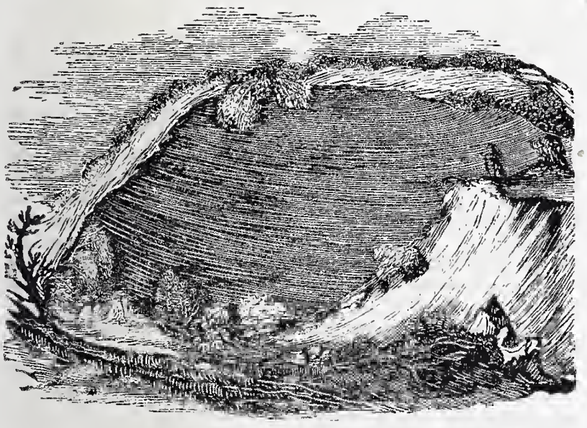
In 1811, South Carolina was very much convulsed by earthquakes. At the same time, the valley of the Mississipi was so affected as to cause the creation of a number of lakes and islands. Eleven years afterward, a tract of land, near the little prairie, several miles in extent, which had then become covered with water three or four feet deep, was found by Flint, the geographer, to be covered with a bed of alluvial sand. During the earthquake, large lakes, 20 miles in extent, were formed in the course of an hour, and others were drained; while the burying-ground of New Madrid was hurled into the Mississipi, and the town itself, and surrounding country, lowered in its level about 8 feet. While the shock lasted, the earth undulated like the waves of the sea—bursting in many places, and vomiting vast quantities of water, sand, and pit-coal, which were flung as high as the tops of the trees,—the earth rending at the time into deep chasms.

The great earthquake which happened in Calabria, in 1783, has offered, more than any other, opportunities to the geologist of examining the effects produced by such convulsions, several scientific gentlemen having examined and reported upon the character and consequences of the earthquake at the time. From a register kept by a physician of the name of Pignataro, it appears that in that year there were experienced in Italy not less than 949 shocks, 501 of which were of the first degree of force; and that in the following year, there were 151, 98 of which were of the same violent nature. The first shock occurred on the 5th of February, in 1783, and threw down in two minutes the greater number of the houses in all the cities and villages from the western flank of the Appenines in Calabria, to Messina in Sicily. The granitic chain which passes from north to south through Calabria was shaken. It is stated that the warlike movements which were propagated through the recent strata, reposing on the flanks of the granite, became dreadfully violent when they reached the point of junction, "as if," says Mr Lyell, "a reaction had been produced where the undulatory movement of the soft strata was suddenly arrested by the more solid rocks." The Appenines, according to Dolomieu, consist chiefly of hard and soft granite, which, with some micaceous and argillaceous schists, form bare precipitous mountains, exhibiting marks of degradation. Flanking the base of these hills are beds of sand and clay, mingled with marine tertiary shells. These beds form the plain of Calabria, which is plain and level, except where intersected by ravines and valleys, which have been excavated by the action of torrents and rivers to the depth, in some instances, of six hundred feet. The sides of these ravines are generally perpendicular; for the upper stratum being bound together by the roots of trees, prevents the formation of a sloping bank. The usual effect, says Dolomieu, of the earthquake was to disconnect all those masses which either had not sufficient bases for their bulk, or which were only supported by lateral adherence. Hence, it follows, that throughout almost the whole length of the chain, the soil which adhered to the granite at the base of the mountains Caulone, Exsope, Sagra, and Aspramonte, slid over the solid and steeply inclined nucleus, and descended somewhat lower, leaving almost uninterruptedly, from St George to beyond St Christina, a distance of from nine to ten miles, a chasm between the solid granitic nucleus, and the sandy soil. Many lands, slipping thus, were carried to a considerable distance from their former position, so as entirely to cover others,

and disputes arose as to whom the property, which had thus shifted, should belong.

"From this account of Dolomieu," says Mr. Lyell, "we might anticipate, as the result of a continuance of such earthquakes, first, a longitudinal valley following the line of junction of the older and newer rocks; secondly, greater disturbance in the newer strata near the point of contact, than at a greater distance from the mountains —phenomena very common in other parts of Italy, at the junction of the Appenine and Subappenine formations."

Many fissures and chasms which had been formed by the previous, were greatly widened by succeeding shocks. Grimaldi mentions a new ravine, in the territory of San Fili, half a mile long, 2½ feet broad, and 25 feet deep; another nearly a mile long, 105 feet wide, and 30 feet deep; another three-quarters of a mile long, 150 feet broad, and above 100 feet deep; and one at La Fortuna, nearly a quarter of a mile long, above 30 feet in breadth, and 225 feet deep; one, of which the following is a drawing, occurred near the town of Oppida, in the side of a hill, 500 feet long, and 200 feet deep.



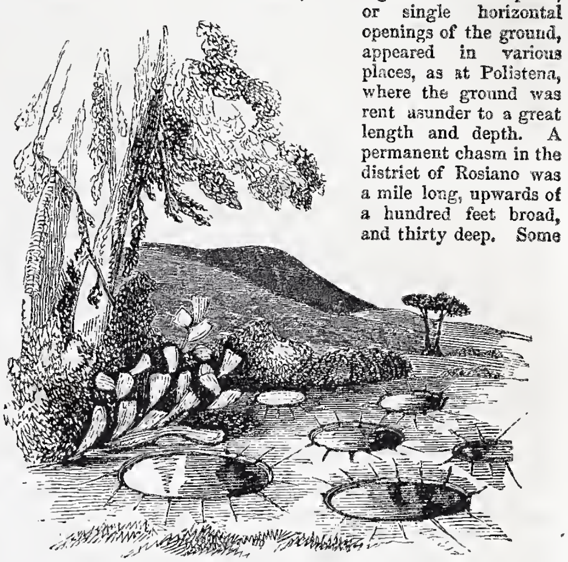
Chasm formed near Oppida in 1783.

In the district of Fosolana, three gulfs opened; one, 300 feet square, and above 30 feet deep; another, about half a mile long, 15 feet broad, and above 30 feet deep.

Dolomieu and Sir William Hamilton made a personal examination of the surface of the Calabrias after the earthquakes, which continued from the beginning of 1783 to the close of 1786, and their survey illustrates the superficial changes produced by the action of such

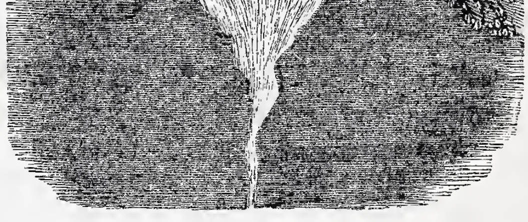
Fissures at Polistena.

events. Those provinces have been subject to such visitations since the first Greek colonists landed on their shores, but the most terrible instances in modern times occurred in 1633 and 1783, in the latter of which Sicily largely participated. The soil of the mainland is chiefly composed of modern marine strata, immensely thick, generally of calcareous clay, of a very yielding nature, which was greatly disturbed, and assumed a variety of new forms, under control of the irresistible force acting upon it. The earth exhibited a variety of motions, whirling like a vortex, horizontal, or by pulsations or beatings from the bottom upwards. Valleys underwent extensive and striking alterations, through the precipitation into them of masses from the neighbouring hills. Fissures, radiating from a central point, or single horizontal openings of the ground, appeared in various places, as at Polistena, where the ground was rent asunder to a great length and depth. A permanent chasm in the district of Rosiano was a mile long, upwards of a hundred feet broad, and thirty deep. Some



Circular hollows at Polistena.

of these fissures, after swallowing up houses and men, closed and opened again, so that property was recovered, and the victims of the catastrophe were restored to the rites of burial. In the plains, a considerable number of circular hollows were formed, filled with water or sand, a consequence of the vorticose or whirling motion of the earth, and on digging down, they were found to be funnel-shaped, and the moist loose sand in the centre, up which the water spouted



Section of one of the circular hollows formed in the plain of Rosiano.

About 40,000 persons are said to have perished amidst the catastrophes of the Calabrian earthquakes, and about 20,000 more died of the epidemics which ensued.

We shall conclude these accounts with a brief notice of three most remarkable and disastrous earthquakes; namely, those which occurred in Jamaica in 1692, at Lisbon in 1755, and at Melfi, near Naples, a few months ago.

The weather had been sultry in Jamaica up to the month of May, when it became very windy and rainy from the end of the month till the 7th of June,—it was excessively hot on the forenoon of that day, when not a cloud was to be seen in the sky, or a breath of air to fan the feverish cheek. A small trembling noise heralded a hollow loud rumbling like that of distant thunder; that was succeeded by a violent shock, which, in one minute, shook Port Royal to its foundation, and three parts of the town with its inhabitants sunk, and were instantly overwhelmed with the rush of the ocean. The houses and wharfs sunk to the

depth of from 8 to 6 fathoms below water—every where the ground heaved and swelled like an agitated sea, cracking, opening, and suddenly shutting; and in many instances, swallowing people alive. Some were totally buried, while others were squeezed to death, their heads only appearing above ground; larger openings swallowed whole houses, and some of these disgorged vast currents of water, which rose to considerable heights in the air, and were accompanied with the most obnoxious vapour and stench. The air, which had been a moment before so serene, became dull and red like an oven; while the most frightful noises came from the mountains, which were rending in pieces; while the ghastly and terror-stricken inhabitants ran from place to place, or were seen staggering and falling in all directions; many plantations with their houses were completely swallowed up; not far from Yellows, part of a mountain, after several removes, overwhelmed a whole family, and the greater part of a plantation more than a mile from its former site. A large hill near Port Morant was swallowed up, and a lake substituted in its place, 4 or 5 leagues in extent. The tops of the mountains in their fall huddled trees and earth before them in the most confused manner, and stopped the passage of several rivers for 24 hours, after which they found out new channels, and brought down to the sea many thousand tons of timber. In the harbour of Port Royal, the shock forced the vessels from their moorings; and the mast heads of several ships, together with the tops of the houses, were afterwards just seen projecting above the water at Yollhouse; the sea retired about a mile, and vast quantities of fish were left on dry land. About 2000 people are supposed to have perished in this catastrophe, and 3000 whites afterwards died of pestilential diseases, caused by the putrid effluvia which issued from the fissures in the earth which had been opened by the earthquake.

On the 1st of November 1755, the city of Lisbon was thrown into dismay by the sound of thunder rolling under the earth, which was immediately succeeded by a violent shock which destroyed the greater part of the city, with 60,000 people who perished in the course of ten minutes. Some of the largest mountains in Portugal were shaken to their very foundations, and cleft and rent in a most extraordinary manner,—some of them emitting flames and hurling enormous masses of rock into the adjoining valleys. The quay at Lisbon, upon which a great concourse of people had collected for safety, sunk in a moment, and not one of the persons upon it escaped. A great number of boats and vessels were swallowed in a whirlpool, no fragment of which ever rose again to the surface. The depth to which the quay sunk, was ascertained to be 100 fathoms. The earthquake was felt throughout nearly the whole of Europe, in Africa, and the West Indies. In Great Britain, rivers and lakes were agitated,—the waters of Lochlomond rose two feet, and then subsided below their usual level. It is calculated that the shock travelled at the rate of about 20 miles a minute. A great wave swept round the coast of Spain, where it rose 60 feet high. The same phenomenon, though to a less extent, was experienced at Madeira, and on the coast of Ireland.

In the summer of the present year, (1851,) Melfi, in the neighbourhood of Naples, so frequently the theatre of those terrible workings of nature, was visited by one of the most disastrous earthquakes of modern times. We quote the account given by an eye-witness, a medical officer, despatched by the Neapolitan Government to the scene of the earthquake in the upper Basilicata:—

"The village of Baville has actually disappeared. I found all about this district large fissures, partly filled up with houses. A man who escaped told me it appeared to him, that for a minute he was being tossed about in the air: the earth appeared, as it were, endowed with a breathing power, and then came a different movement—a shaking to and fro. Here some military had arrived to excavate. There was a strong stench of decomposing bodies. This place was really deserted by the inhabitants; at least, I saw very few. How shall I give you an idea of what was once the town of Melfi? The cathedral is down, as are the college, the churches, the military depot, and 163 houses—98 are in a falling state, and 180 pronounced as dangerous. The military have arrived, and are working away. Our medical staff is by no means strong enough. More than a thousand bodies have already been dug up; I need not add, all dead. The wounded are over 600, and present every variety of flesh-wounds and fracture. Sixty-five boys of the college of Melfi are supposed to have perished. The calamity took place when most of the population were sleeping, as is the custom in Italy after dinner."

At the Police Office in Naples, on the 27th August, they replied to inquiries—"Up to this day the returns of dead bodies, dug out of the ruins from all towns and villages, is 857; but the excavations have only commenced."

Much more might be cited to show the devastation wrought by earthquakes, and their effects in producing changes in the configuration of the districts in which they occur; but enough has been adduced to satisfy the reader, that there resides in the interior parts of the earth,—agencies, which when awakened, are capable of producing all that alteration with which we are impressed, as having taken place in almost every geological epoch, when we survey the shattered, twisted, and contorted condition of the rocks which compose the crust of the earth.

## ANATOMY AND PHYSIOLOGY.

### CHAPTER VIII.

THE MUSCLES AND MUSCULAR ACTION.—*Continued.*

The muscular system, like other parts of the body, possesses the faculty of conservation and self-reparation. When a muscle is exhausted and lacerated, the circulating blood deposits the necessary elements to preserve and repair it. A muscle has the inherent power of applying the elements of the blood to the renovation of its substance, and the reparation of its injuries; and in a state of healthy action, easily effects the conservation, and restores the integrity of its lacerated parts.

During the juvenile growth of the muscles, the same animal law is established for their enlargement that in old age is required to preserve them from decay. In both cases, the circulating blood supplies the necessary elements for growth and preservation. The order, promptitude, and facility with which the muscles perform their vital functions, and extract from the blood the individual elements only that are required for their necessities, is one of the unanswerable arguments, that the Author of our existence is not only an infinitely powerful, but a provident Being.

The muscles, like other animal substances, are liable to diseases that sometimes require the aid of operative surgery. Surgical operations reflect very little honour on the art of healing; because they prove that the healing art is still imperfect. If it were perfect, there would be no necessity for operative surgery; yet sometimes, great operative surgeons appear to be prouder of having successfully performed a great operation, than of having accomplished the cure of a morbid disease by the materia medica. The cure of a morbid disease reflects more honour on the healing art, than the successful performance of a great operation. Sometimes we might almost be tempted to conclude, that the end and aim of the great operative surgical mania, is to ascertain *secundum artem*, with how little of his *corpus* a human being may be made to exist. Yet when the healing art pronounces a cure impossible, there is no other alternative even for the most humane surgeon, than to operate; and it is better to part with an incurable morbid portion of the body, and preserve life, than permit it to remain and destroy our existence.

Some men have large powerful muscles; others puny and weak. There are fixed animal laws that regulate their growth and preservation; and by obeying them, any person may attain the muscular maximum that belongs to his constitution. The hardy mountaineer climbs his native hill with vigour, elasticity, and ease, chases the nimble goat, and pursues the bounding deer, unfatigued for a long summer's day. The delicate lady, confined to the city, and nursed in effeminacy, pants for breath when travelling on the green lawn after half an hour's Lilliputian journey. The too early confinement of children at school, super-exercises and injures their brain, and renders their muscles puny and debilitated. The muscles of the hardy peasant child, accustomed to exercise, are larger and more powerful than those of the less fortunate girl confined to factory labour. Children should be allowed the free exercise of their muscles, if we would

have them enjoy health and become robust. Disease and death destroy more children and adults in large cities, than in rural districts. Dr Farr states, that out of equal proportions of English inhabitants, in a given time, 47 die in cities, and 29 in the country. One-half of all the deaths in Glasgow, during the last ten years, were children under five years old. These are appalling facts, and humanity demands an immediate legislative remedy for the prevention of this human destruction. If mechanical and agricultural labour were usefully combined; and if the population were more extended over the country, instead of being pent up into large overcrowded cities, the *muscles* of the population would speedily attain their due development, and death would ensue only from natural causes.

Unless the body be regularly supplied with plenty of nutrient diet, the muscles will lose their vigour and soon decay. There is a continual waste going on. To supply the carbon for respiration during a day, supposing that the individual takes moderate exercise, and throws off 8 oz. of that element in the form of carbonic acid, he requires 18 oz. of starch, which is equivalent to $1\frac{3}{4}$ lbs. of wheaten bread, or $7\frac{1}{2}$ lbs. of potatoes; and to repair the waste of his muscular system, he requires during the same time to assimilate from his food not less than 350 grains of nitrogen, that is, as much nitrogen as is contained in 5 oz. of gluten or fibrin. Now $1\frac{3}{4}$ lbs. of bread contain 3 oz. of gluten, and $7\frac{1}{2}$ lbs. of potatoes contain $2\frac{1}{2}$ oz. of that constituent; in the one case there therefore remains to be supplied 2 oz., and in the other, $2\frac{1}{2}$ oz. of gluten; and suppose the deficiency to be made up with beef; 8 oz. with $1\frac{3}{4}$ lbs. of bread, or 10 oz. with $7\frac{1}{2}$ lbs. of potatoes, are the calculated quantities of diet which are essential to the maintenance of the animal system in a healthy state. If a man would attempt to live on bread alone, he ought to consume 3 lbs. per day; in the case of potatoes, no less than 15 lbs. I shall now proceed to the muscles of the lower extremities.

The muscles that move the thigh bone are the 14 following: 1st, Tensor vaginæ femoris; 2d, Psoas magnus; 3d, Psoas parvus; 4th, Iliacus internus; 5th, Pectinalis; and 6th, The Triceps femoris, which is subdivided into the three following branches; viz., Adductor longus, adductor brevis, and adductor magnus. These six muscles move the thigh forward, point the toes inward, and are inserted as follows:—The Psoas magnus and Iliacus internus, into the trochanter major of the thigh bone, and the pectinalis and triceps into the linea aspera. The first three of the remainder of these fourteen muscles are; 7th, The Glutæus maximus; 8th, Glutæus medius; and 9th, The Glutæus minimus. These three move the thigh-bone backward and outward, and are inserted as follows:—The Glutæus maximus into the linea aspera; the Glutæus medius into the trochanter major, and Glutæus minimus into the top of the trochanter. The remaining five muscles are; 10th, The Obturator externus; 11th, The Gemini, which some anatomists subdivide into two; 12th, The Obturator internus; 13th, The Quadratus femoris; and 14th, The Pyriformis. These five move the thigh-bone backward, roll it on its axis, and are also inserted as follows:—The Obturatores externus and internus, the pyriformis and gemini into the root of the trochanter and the quadratus, betwixt the trochanters. These fourteen large fleshy muscles (*in toto*) assist in forming the contour of the thigh, and perform many of its most powerful and useful actions.

There are four muscles that extend the leg:—1st, The Rectus femoris; 2d, Cruræus; 3d, Vastus internus; and 4th, Vastus externus. These large muscles assist in forming the thigh, and are all implanted by one strong tendon into the patella, or knee-lid. But the vastus externus and internus also send some fibres to be inserted on the outer part of the head of the tibia or great bone of the leg,—the knee being a hinge-joint, these four muscles extend the leg, bend the thigh on the trunk, and are the great agents in running, leaping, and walking. There are six Flexor muscles that bend the leg:—1st, The Sartorius, or Tailor's muscle, by which the legs are crossed; 2d, Gracilis; 3d, Semitendinosus; 4th, Semimembranosus; 5th, Poplitæus; and 6th, Biceps cruris. The first four are inside flexors, and their tendons are inserted into the rough head of the tibia, or large bone of the leg; they also form the hamstrings, and extend their aponeurotic expansions downward upon the leg. The tendon of the biceps is implanted into the upper knob of the fibula, or small bone of the leg, and the poplitæus is inserted broad into a ridge on the back part of the tibia. These muscles form part of the fleshy and tendinous substance of the ham and thigh. There are six Extensor muscles of the foot; the first four, viz., 1st, The gastrocnemius; 2d, The plantaris; 3d, The solæus; and 4th, Tibialis posticus, lie on the back part of the leg; and the last two, viz., 5th, The perinæus longus; and 6th, perinæus brevis, lie on the outside of the leg. These extensor muscles are useful in running, walking, and leaping. There are also two flexor muscles of the foot, that bend it when acting together, lying on the fore part of the leg, viz., the tibialis anticus, and the perinæus tertius. The tendon of Achilles, (or the thick cord which is attached to the heel-bone, and forms the inferior posterior portion of the leg,) is formed by the union of the solæus and gastrocnemius muscles. There are sixteen muscles of the toes that move them in every direction,—their names generally denote their uses: flexion, extension, abduction, and adduction, are performed by their action. 1st, Flexor longus pollicis; 2d, Flexor longus digitorum pedis; 3d, Massa carnea; 4th, Flexor brevis digitorum; 5th, Lumbricalis; 6th, Extensor longus digitorum pedis; 7th, Extensor digitorum brevis; 8th, Extensor pollicis proprius, and the crucial ligaments; 9th, Abductor pollicis; 10th, Flexor brevis pollicis; 11th, Adductor pollicis; 12th, Transversalis pedis; 13th, Abductor minimi digiti; 14th, Flexor brevis minimi digiti; 15th, Interossei interni; 16th, Interossei externi, 17th, The plantaris aponeurosis is a thick aponeurotic expansion that defends the sole of the foot, and protects the blood-vessels, muscles and nerves, that lie under it from external injury. Sometimes contraction of the aponeurosis contracts the foot and deforms it. The toes are drawn inward and toward the sole of the foot, impeding its mechanical movements. The cure is accomplished by dividing the aponeurosis with a long thin knife nicely introduced underneath the skin. The foot is afterwards retained in a proper extended position, and subsequent inflammation prevented till it heals.

I was lately present when this simple operation was very adroitly performed on a boy, by an hospital surgeon. The aponeurosis of his foot was contracted, and also the tendo-Achilles. His toes were bent inward and downward, and his heel drawn upward and backward,—as soon as the aponeurosis and tendo-Achilles were divided, the foot partially resumed a natural position. A case of this kind requires a great deal of skilful management, even after the operation, and several weeks must elapse before it is cured.

Some of the French surgical authors inform us, that clubfoot contractions generally resume their original deformity, about four years after an operation. It would be desirable that the ultimate progress of such cases were also strictly watched by British surgeons, and reported to the profession. If the French authors are correct with these statements, it would not be very desirable for a patient to endure the operation, with the certainty of a relapse. I am aware that some cases of *squinting* partially corrected by recent surgical operations, have again resumed their original obliquity.

The flexors and extensors, the adductors and abductors of the toes, are antagonist muscles; the flexors bend the toes downward; the extensors raise them upward; the adductors draw them inward, and the abductors outward. And much in the same manner, the antagonists of the leg also act upon the foot, and move it by the ankle-joint in every possible direction. The mechanism of the leg and foot is beautiful and perfect, and nothing that science has invented can equal its beauty and utility. By the simple and combined action of a few bones and muscles, we climb, walk, run, leap, dance, &c., and perform tumbling and equestrian feats; without the muscles of the lower extremities, we should be obliged to stand immovable like statues, and vegetate like plants; yet aided by the simple, combined, and harmonious muscular machinery, we can move our joints at pleasure, and travel from place to place with agility and ease. By their powerful action, we climb the wild hills of Scotland and Wales—ascend the hoary Alps—mount the gigantic Andes, and overtop the almost insurmountable Himalayas. By their mechanical power we descend valleys, cross ravines, bogs, and marshes—traverse the sandy deserts of Africa, and the green prairies of America—parade through the richest kingdoms and capitals of the world, and visit the sublimest scenery of nature. The youthful, stout, active, and comfortable *pedestrian*, pursuing his voluntary journey without encumbering equipage in fine summer weather, and occasionally pausing on his

way, to admire the beauties of nature, and gaze on the relics of past ages, is the happiest and most independent of travellers; and as he cheerily passes along his road, trusting only to the powerful *muscles* of his lower extremities, to carry him to the end of his journey, he feels an elasticity of body, and a buoyancy of mind, indescribably pleasant; and as he exercises the active *muscles* of his limbs, and inhales the pure air, he imparts strength to the whole muscular system, and feels enjoyment that will delight him in his future years, with the sweetest reminiscences of the pleasures of the travels of the past.

The man who has never examined and studied the mechanism and functions of the *muscles* is apt to conclude, that the flesh is a solid mass, without any other use than to cover the bones, and constitute by its bulk, the external portion of the body. But when he minutely examines its anatomy and physiology, he perceives that it is mechanically constructed, and separated into long, broad, thin, layers; lying side by side, and above each other, and that each muscle is composed of long, slender fibres, each enclosed in its own cellular sheath; and that individually and combined, they perform every motion of the animal machine. It is the muscular system that chiefly distinguishes the activity of animals from vegetables, and gives the faculty of locomotion to the one, and immovability to the other. Yet some plants exhibit muscularity in a very limited extent. The sensitive plant shrinks its leaves from the touch of the human finger. The Venus fly-trap shuts its leaves on the insect that preys on the sweets of its bosom, and crushes it to death. The sunflower opens its bosom to the rising sun, and follows his course during day; and at night again closes its beautiful leaves, when the sun is absent. These are undoubtedly muscular actions, and, as far as they extend, are little inferior to the muscular motions of zoophites and some of the lowest tribes of animal existences. But the complete faculty of locomotion is denied them, and man and animals alone enjoy it in perfection. The creeping plants make the nearest approximation to the locomotion of animals.

On some parts of the body, particularly over the temporal muscles, the abdomen, the back, the arms, and thighs, a strong broad *fascial* membrane is spread over the muscles, to protect, cover, and give them firmness. This partial covering, by its gentle and powerful expansion, defends the internal parts from injury, and facilitates muscular motion.

When we thus look with philosophical minds into the great arcana of animated nature, and accurately comprehend it, we discover the *visible* presence of that *invisible* Being, who sits in mysterious silence behind the elements he has formed, and gives birth and movement to every atom.

We have now finished the muscles. The accompanying plates will enable the reader to determine their localities with accuracy. In the next essay we shall begin to describe the bones, and we may safely promise that the subject will become more interesting as we advance.

## BIOGRAPHY.

### THOMAS SIMPSON, F.R.S.

This very eminent mathematician was born at Market Bosworth, in the county of Leicester, the 20th of August, 1710. His father was a stuff-weaver in that town; and though in tolerable circumstances, yet, intending to bring up his son Thomas to his own business, he took so little care of his education, that he was only taught to read English. But nature had furnished him with talents and a genius for far other pursuits, and which led him afterwards to the highest rank in the mathematical and philosophical sciences.

Young Simpson very soon gave indications of his turn for study in general, by eagerly reading all books he could meet with, teaching himself to write, and embracing every opportunity he could find of deriving knowledge from other persons. His father observing him thus to neglect his business, by spending his time in reading what he thought useless books, and following other similar pursuits, used all his endeavours to check such proceedings, and to induce him to follow his profession with steadiness and better effect. And after many struggles for this purpose, the differences thus produced between them at length rose to such a height, that young Simpson quitted his father's house to seek a home for himself.

On this occasion he repaired to Nuneaton, a town at a small distance from Bosworth, where he went to lodge at the house of a tailor's widow, of the name of Swinfield, who had been left with two children, a daughter and a son, by her husband, of whom the son, who was the younger, being but about two years older than Simpson, had become his intimate friend and companion. And here he continued some time, working at his trade, and improving his knowledge by reading such books as he could procure.

Among several other circumstances which, long before this, gave occasion to show our author's early thirst for knowledge, as well as proving a fresh incitement to acquire it, was that of a solar eclipse, which took place on the 11th day of May, 1724. This phenomenon, so awful to many who are ignorant of the cause of it, struck the mind of young Simpson with a strong curiosity to discover the reason of it, and to be able to predict the like surprising events. It was, however, several years before he could obtain his desire, which at length was gratified by the following accident. After he had been some time at Mrs Swinfield's at Nuneaton, a travelling pedlar came that way, and took a lodging at the same house, according to his usual custom. This man, to his profession of an itinerant merchant, had joined the more profitable one of a fortuneteller, which he performed by means of judicial astrology. Every one knows with what regard persons of such a cast were treated by the inhabitants of country villages; it cannot be surprising, therefore, that an untutored lad of 19 should look upon this man as a prodigy, and, regarding him in this light, should endeavour to ingratiate himself into his favour; in this he succeeded so well, that the sage was no less taken with the quick natural parts and genius of his new acquaintance. The pedlar, intending a journey to Bristol fair, left in the hands of young Simpson an old edition of Cocker's Arithmetic, to which was subjoined, a short appendix on Algebra, and a book upon Genitures, by Partridge the almanac-maker. These books he had perused to so good purpose, during the absence of his friend, as to excite his amazement upon his return; in consequence of which he set himself about erecting a genethliacal figure, in order to a presage of Thomas' future fortune.

This position of the heavens having been maturely considered, *secundum artem*, the wizard with great confidence pronounced, that, "within two years' time, Simpson would turn out a greater man than himself!"

In fact, our author profited so well by the encouragement and assistance of the pedlar, afforded him from time to time when he occasionally came to Nuneaton, that, by the advice of his friend, he at length made an open profession of casting nativities himself; from which, together with teaching an evening school, he derived a pretty pittance; so that he greatly neglected his weaving, to which indeed he had never manifested any great attachment, and soon became the oracle of Nuneaton, Bosworth, and the environs. Scarce a courtship advanced to a match, or a bargain to a sale, without previously consulting the infallible Simpson about the consequences. But as to helping the people to stolen goods, he always declared that above his skill; and over life and death he declared he had no power: all those called lawful questions he readily resolved, providing the persons were certain as to the horary data of the horoscope; and, he has often declared, with such success, that if from very cogent reasons he had not been thoroughly convinced of the vain foundation and fallaciousness of his art, he never should have dropt it, as he afterwards found himself in conscience bound to do.

About this time he married the widow Swinfield, in whose house he lodged, though she was then almost old enough to be his grandmother, being upwards of fifty years of age. After this the family lived comfortably enough together for some short time, —Simpson occasionally working at his business as a weaver in the daytime, and teaching an evening school or telling fortunes at night; the family being also further assisted by the labours of young Swinfield, who had been brought up in the profession of his father.

But this tranquillity was soon interrupted, and our author driven at once from his home and the profession of astrology, by the fol-

lowing incident. A young woman in the neighbourhood had long wished to hear or know something of her lover, who had been gone to sea; but Simpson had put her off from time to time, till the girl grew at last so importunate, that he could deny her no longer. He asked her if she would be afraid if he should raise the devil,—thinking to deter her; but she declared she feared neither ghost nor devil,—so he was obliged to comply. The scene of action pitched on was a barn, and young Swinfield was to act the devil or ghost; who, being concealed under some straw in a corner of the barn, was, at a signal given, to rise slowly out from among the straw, with his face marked, so that the girl might not know him. Every thing being in order, the girl came at the time appointed; when Simpson, after cautioning her not to be afraid, began muttering some mystical words, and chalking round about them, till, on the signal given, up risos the tailor slow and solemn, to the great terror of the poor girl, who, before she had seen half his shoulders, fell into violent fits, crying out it was the very image of her lover; and the effect upon her was so dreadful, that it was thought either death or madness must be the consequence; so that poor Simpson was obliged immediately to abandon at once both his home and the profession of a conjuror.

On this occasion it would seem he fled to Derby, where he remained about two or three years; viz., from 1733 till 1735 or 1736; instructing pupils in an evening school, and working at his trade by day.

It would seem that Simpson had an early turn for versifying, both from the circumstance of a song written here in favour of the Cavendish family, on occasion of the parliamentary election at that place, in the year 1733, and from his first two mathematical questions that were published in the Ladies' Diary, which were both in a set of verses, not ill written for the occasion. These were printed in the Diary for 1736, and therefore must at latest have been written in the year 1735. These two questions, being at that time pretty difficult ones, show the great progress he had even then made in the mathematics; and from an expression in the first of them, viz., where he mentions his residence as being in latitude 52°, it appears he was not then come up to London, though he must have done so very soon after.

Together with his astrology he had soon furnished himself with arithmetic, algebra, and geometry, sufficient to be qualified for looking into the Ladies' Diary, (of which he had afterwards for several years the direction,) by which he came to understand that there was a still higher branch of the mathematical knowledge, than any he had yet been acquainted with; and this was the method of Fluxions. But our young analyst was quite at a loss to discover any English author who had written on the subject, except Mr Hayes; and his work being a folio, and then pretty scarce, exceeded his ability of purchasing: however, an acquaintance lent him Mr Stone's Fluxions, which is a translation of the Marquis de l'Hopital's Analyse des Infinimens Petits: by this one book, and his own penetrating talents, he was, as we shall see presently, enabled in a very few years, to compose a much more accurate treatise on this subject than any that had before appeared in our language.

After he had quitted astrology and its emoluments, he was driven to hardships for the subsistence of his family, while at Derby, notwithstanding his other industrious endeavours in his own trade by day, and teaching pupils at evenings. This determined him to repair to London, which he did in 1735 or 1736; and wrought for some time at his business in Spitalfields, and taught mathematics at evenings, and other spare hours. His industry turned to so good account, that he returned down into the country, and brought up his wife and three children—she having produced her first child to him in his absence. The number of his scholars increasing, and his abilities becoming in some measure known to the public, he was encouraged to prepare for publication his first work. This was a new treatise on Fluxions, and was published by subscription in 1737. Such was its reception, that, in 1740, he published a treatise on the nature and laws of chance, which was followed in the same year, with his essays on several curious and interesting subjects in speculative and mixed mathematics. These works extended his reputation even to foreign countries, and he was elected a member of the Swedish Academy of Sciences. His doctrine of annuities and reversions appeared in the same year, and an appendix to it in 1741. Supported by the influence of Mr. Jones, the father of Sir William, our author was, in 1743, appointed professor of mathematics in Woolwich, and the same year he published his mathematical dissertations. In 1745, he was admitted a fellow of the Royal Society, having been excused his admission fees on account of his limited income. In 1744, he published his treatise on Algebra, which was enlarged in 1755, and in 1757, his elements of Geometry, which was reprinted in 1760, and subsequent years. In 1748, he printed his Trigonometry plane and spherical, with the construction and application of Logarithms. His select exercises for young proficients in mathematics appeared in 1752, and his last work, viz., his miscellaneous tracts, came out in 1757. Mr Simpson was likewise the author of several papers which appeared in the philosophical transactions, and he edited the Lady's Diary from 1754 till 1760, a work to which he had been a contributor from 1736, and which he raised to a very high degree of respectability.

It has been commonly supposed that he was the real editor of, or had a principal share in, two other periodical works of a miscellaneous mathematical nature; viz. the Mathematician, and Turner's Mathematical Exercises, two volumes, in 8vo, which came out in periodical numbers, in the years 1750 and 1751, &c. The latter of these seems especially to have been set on foot to afford a proper place for exposing the errors and absurdities of Mr Robert Heath, the then conductor of the Ladies' Diary and Palladium; and which controversy between them ended in the disgrace of Mr Heath, and expulsion from his office of editor to the Ladies' Diary, and the substitution of Mr Simpson in his stead, in the year 1753.

In the year 1760, when the plans proposed for erecting a new bridge at Blackfriars were in agitation, Mr Simpson, among other gentlemen, was consulted on the best form for the arches, by the new bridge Committee. On this occasion he gave a preference to the semicircular form; and, besides his report to the Committee, some letters also appeared by himself and others, on the same subject, in the public newspapers, particularly in the Daily Advertiser, and in Lloyd's Evening Post. The same were also collected in the Gentleman's Magazine for that year, pp. 143, and 144.

It is probable that this reference to him gave occasion to the turning of his thoughts more seriously to this subject, so "as to form the design of composing a regular treatise upon it: for his family have often informed me, says Dr Hutton, that he laboured hard upon this work for some time before his death, and was very anxious to have completed it,—frequently remarking to them, that this work, when published, would procure him more credit than any of his former publications. But he lived not to put the finishing hand to it. Whatever he wrote upon this subject, probably fell, together with all his other remaining papers, into the hands of Major Henry Watson, of the engineers, in the service of the India Company, being in all a large chest full of papers. This gentleman had been a pupil of Mr Simpson's, and had lodged in his house. After Mr Simpson's death, Mr Watson prevailed upon the widow to let him have the papers, promising either to give her a sum of money for them, or else to print and publish them for her benefit. But neither of these was ever done;—this gentleman always declaring, when urged on this point by myself and others, that no use could be made of any of the papers, owing to the very imperfect state in which he said they were left. And yet he persisted in his refusal to give them up again."

At the Academy he exerted his faculties to the utmost, in instructing the pupils who were the immediate objects of his duty, as well as others, whom the superior officers of the ordnance permitted to be boarded and lodged in his house. In his manner of teaching, he had a peculiar and happy address; a certain dignity and perspicuity, tempered with such a degree of mildness, as engaged the attention, esteem, and friendship of his scholars; of which the good of the service, as well as of the community, was a necessary consequence.

In the latter stage of his existence, when his life was in danger, exercise and a proper regimen were prescribed him, but to little purpose; for he sank gradually into such a lowness of spirits, as often in a manner deprived him of his mental faculties, and at last rendered him incapable of performing his duty, or even of reading the letters of his friends; and so trifling an accident as the dropping of a tea-cup would flurry him as much as if a house had tumbled down.

The physicians advised his native air for his recovery; and in February, 1761, he set out, with much reluctance (believing he should never return), for Bosworth, along with some relations. The journey fatigued him to such a degree, that on his arrival he betook himself to his chamber, where he grew continually worse and worse, to the day of his death, which happened the 14th of May, in the fifty-first year of his age.

# ILLUSTRATIONS OF MECHANICAL DRAWING.

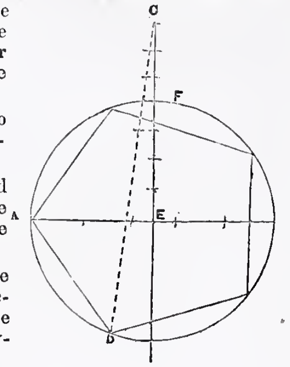
## CHAPTER III.

Problem XX. To describe any regular polygon in a given circle.

1. Let A F B D, be the given circle. Draw the diameter A B. From E as a centre, erect the perpendicular E F C, cutting the circle at F. Divide E F into four equal parts, and set off three similar divisions from F to C.

2. Divide the diameter A B into as many equal parts as the polygon is required to have sides.

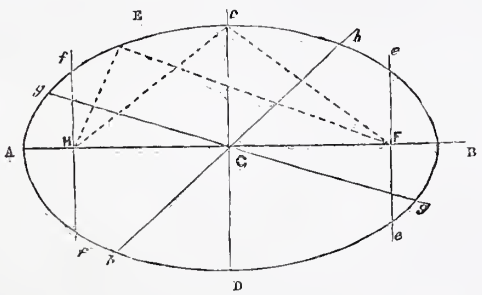
3. From C through the second division in the diameter draw the line C D, and A D shall be the side of the polygon required.




In each of these examples we have shown a pentagon on account of its simplicity, but the same rule is applicable to polygons of any number of sides.

### Of the Ellipse.

The fact of circular surfaces changing their appearance with the different positions of the observer's eye, is so well known as to render any observations on that head needless, but in order to delineate them under all circumstances, it is essentially requisite that the student should understand that the elliptical curve thus assumed by the circular one, is strictly regular, and is to be produced by rules as fixed and certain, as that by which we describe the circle itself. With the assistance of the annexed figure, which we have selected as a familiar explanation of the principles of the ellipse, the student will have no difficulty in understanding the plain definition of it. The line A B passing through the length of the figure is called its *transverse axis*.




The point G which bisects the transverse axis, is the *centre* of the ellipse. The line C D crossing this centre at right angles to the transverse axis, is termed the *conjugate axis*.

The point F in the transverse axis, and corresponding point H at the same distance from the centre on the other side, are called the *foci* of the ellipse.

A right line *f f* or *e e* passing through a focus of the figure at right angles to the transverse axis, and terminated at either end by a curve is called the *latus rectum* or sometimes the parameter.

A straight line passing in any direction through the centre of the figure and terminated at either end by the curve, as *g g* or *h h* is called a diameter,

A line drawn through any diameter parallel to a tangent at the extremity of that diameter terminated by a curve, is called a *double ordinate.*

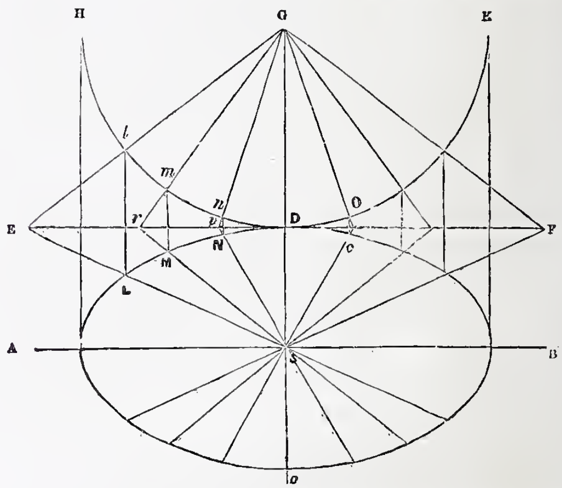
The ellipse is constructed by the motion of a point about the centre of the figure G, beginning its course at the extremity of a diameter, as at A, and taking such a path as that its distance from one of the foci, together with its distance from the other, shall be in every point throughout its course exactly equal to the whole length of the transverse axis A B. A practical application of this principle is to be found in the following method, which is often resorted to in the workshop for producing an ellipse. In the preceding figure, if the transverse and conjugate axes are given, the *foci* are determined by taking half the transverse axis, as A G, and with that extent in the compasses and on the extremity C of the conjugate as a centre, describing an arc, which cuts A B in the points F and H, which are the *foci*.

If pins are fixed in these points, and a thread equal in length to the transverse axis is fastened to them by its extremities, a pencil so applied to the thread as to keep it continually stretched, or forming two straight lines, will, if progressively moved about the centre, describe the ellipse. Thus in the figure before us, H C F, may be supposed to be the thread, which if gradually moved round the centre, will, at different points of its travel take the position of the inclined lines H and E F, describing by the entire revolution of the pencil, the ellipse A C B D.

Problem XXI. The transverse and conjugate diameters of an ellipse being given, as A B and C D, to describe the curve itself through a number of points, to be determined at the extremities of any number of diameters at pleasure.

1. Through the extremity D, of the conjugate axis, draw E F parallel to the transverse axis; extend the line C D to G, and make it equal to A S or S B, half the transverse axis.

2. Upon G, with the radius G D, describe the circle H D K; through the centre S, draw the lines S L E, S M *r*, &c. at pleasure, respectively cutting the line E F at E *r*, &c. Join the points thus determined on the line E F with the centre G, and mark




the points of intersection produced on the arc H D K at *l m n o*, &c.; draw lines from H *l m*, &c. parallel to G D, until they respectively intersect the extremities of the diameter at A, L, M, N, &c.; these points will be in the periphery of the ellipse, and a curve traced through them will describe the figure.

# HISTORY.

## CHAPTER VI.

ROME.—(*Continued.*)

We now come to the first period of the real history of Rome. This extends to the 363d, or, according to some, to the 387th year of the city. The first inquiry of interest which presents itself is its government. It is admitted upon all hands, that the early constitution of the city was monarchical: this period of its annals, however, is so mixed up with legendary fable, that it would be absolute waste of time to attempt to winnow the few grains of truth from the immense heap of chaff. The earlier

systematic writers of Roman history have made matters worse. They have set themselves to build up the complicated Roman constitution from simple elements according to the suggestions of their own fancy; and, taking the names of the few Roman kings preserved by tradition, they have attributed one part of the structure to one, and another part to somebody else, in order to lend a semblance of probability to their own conjectures. All that we can do—relinquishing the hope of attributing the laws to their real authors—is to collect the scattered notices that have survived, of the position of the city in different years within this period, and from them to infer the development of its constitution. The history of the constitution, during this period, is the history of a strictly *municipal* constitution. At the close of the period, the city was the Roman state; for the neighbouring states took advantage of the weak condition to which it had been reduced by the Gauls, to hem it in on all sides. At no time had its domain extended far from the city walls. It is true that at times victory enabled Rome to exercise a greater influence among the confederated states in her neighbourhood, than at others; but during the whole of this period, Rome proper was the city, and all her institutions sprung from the relations in which the denizens of this narrow space stood to one another.

The city is understood to mean that space around which walls had been erected, previous to the expulsion of the kings in the year of the city 244. Within this space, however, there were several burghs with their own fortifications and walls of defence. The capital was fortified in such a manner that it was successfully defended against the Gauls, after these invaders had made themselves masters of the rest of the city. The Aventine had its fortifications apart, as we learn from an event which took place at the time of the secession of the plebeians to the Mons Sacer, on account of their oppression by the patricians. While the rest of Rome was held during these civil dissensions by the patricians and their defendants, the Aventine was retained as a stronghold by the plebeians; and on several occasions, both previous and subsequent to the secession to the sacred mount, we see that the plebeians regarded the Aventine as more especially their own quarter. The Palatine, too—the city more especially ascribed to Romulus—seems to have had its own separate defences.

These separate establishments within the walls of Rome, suggest at once the idea that each of the hills upon which the imperial city stood, may have been originally the seat of the establishment of an independent tribe. *Roma* is not an Italian word, and is conjectured to have been the name of a Pelasgian settlement on the Palatine. The Quirinal appears from the earliest times to have been settled by the Sabines, an Ascan race. From the designation of the inhabitants of this hill,—Cures, or Quires—comes the word Quirites, of frequent and important occurrence in Roman history. The necessity of union against the aggressions of the Tuscans, forced a union between those neighbouring settlements of which a trace remains in the formal designation, so long retained by the citizens, of *populus Romanus et Quirites*. Similarity of names leads us to believe that the descendants of these different races formed the two great original tribes of Rome, the *Ramnes* and the *Tities*. This union is also supposed to have given rise to a deity peculiar to the Romans—the double-headed Janus—the opening and shutting of whose temple was indicative of war or peace, and the site of whose temple was on the boundary line between the district of the Quirinal and the Palatine. There was a third tribe in old Rome,—the Luceres, whose origin cannot be so satisfactorily traced; but many concurring circumstances lead us to attribute it to a Tuscan colony settled on the Cælian mount. These three are the oldest divisions of the Roman citizens of which any record has been preserved. Each had its own region; these tribes had the right of intermarriage; and from them the senate was filled.

The admission of other communities at a later date, as the union of these three had made them strong enough to prescribe terms, was upon less favourable conditions; and this seems to have been the origin of the distinction into patricians and plebeians. The patrician was not necessarily a senator—he was only of those houses whose members were capable of being inscribed into the senate. The more recently admitted tribes found the posts of government filled by the old tribes exclusively; and, contented, in the first instance, with reception into the bosom of so powerful a state, they made no claim to the privilege of filling them. Hence the distinction among the free members of the state, into the patricians who reserved for themselves the magisterial and priestly offices; and the plebeians, the arms-bearing freemen. Time augmented the number of the plebeians; for every person admitted to the Roman citizenship went to swell their ranks; and of this class were many who, in the states they belonged to by birth, had themselves been noble. While the plebeians were thus increasing in consequence, by reason of their number, and by reason of the ambition and intelligence of individuals among them, the germs of disunion were rapidly developing themselves among the less numerous patricians. The most powerful—through wealth, connexions, and the influence of talent—naturally obtained important offices in the state; and the possession of these in turn increased their strength. Office became thus in a manner hereditary in a family. The patricians came to be divided into the greater and lesser houses. The greater houses arrogated a superiority over the lesser on the one hand; while on the other, they were engaged in constant feuds and contests for ascendancy amongst themselves.

In an elective monarchy, such as that of Rome, these proud and powerful houses were objects of suspicion to the monarch; and, indeed, the whole patrician race, proud of their privileges, were less amenable to his dictates than the plebeians. It was therefore the natural policy of the monarchs to conciliate the plebeians, as a counterbalance to the excessive powers of the patricians. The plan resorted to was that of conferring political privileges upon the commonalty; and with this view the city and territory of Rome were cantoned out into divisions, and the plebeian inhabitants of each enrolled as a tribe. The number of these plebeian tribes varied; at one time it is understood there were only sixteen of them—latterly, there were upwards of thirty. The plebeians formed the body of the army—the invincible Roman infantry; and as such, seem to have had, from the first institution of the plebeian tribes, the power of instituting their own tribunes. They had also the power of electing judges to decide in legal controversies between them. The senatorial judges were originally termed arbiters: the *judex*, or judge, in the proper acceptation of the word, was the plebeian judge. Besides this, the plebeians had the power of taxing themselves, when imposts were necessary; and laws were in general submitted to their public meetings for sanction.

The intermediate order, between the senatorial or patrician, and the plebeian, was the result of military policy. The equestrian dignity was long merely personal. Conferred by the discharge of a certain military duty, and that duty incurred by the possession of a certain amount of wealth—it was long before the equestrian rank obtained any political importance, nor had it ever any very well-defined political functions.

The expulsion of the Tarquins was the work of the patricians. The plebeians had been alienated by the oppressions of the last of that race; but the immediate cause of his overthrow was, as often happens, less immediately occasioned by this misgovernment, than by a wanton insult offered to an individual. That individual happened to be noble—a relation of the tyrant himself—and the noble houses made common cause. The only alteration produced by this event in the constitution of the Roman government, was in the attributes of the chief magistrate. None of the proud nobles would give way to any one of their number, and the office of chief magistrate it was resolved should be held for a limited period—the selection of the individual being made, as under the original monarchy, by popular election. The time for which the office was to be held does not seem at first to have been definitely settled, and the title of the dignitary varied. It was some time before annual elections were agreed upon, and the term consul permanently adopted. The office was regal in everything but the name and the duration.

In every other respect the frame-work of Roman society continued as before. The laws were passed, as men were awakened by events to a sense of their necessity, by the senate, and sanctioned by the people. Judgments were pronounced by the warden of the city, the arbiters of the senate, and the judges of the plebeians. The pontiffs and augurs continued, as well as the chief magistrate, to be selected from the greater patrician houses; and this fellowship in office, while it excited occasional jealousies, produced at the same time a strong sense of common interest among them. They began to strengthen themselves by collecting strong dependencies of clients, composed of freedmen and other needy retainers, to whom they gave grants of land.

They formed alliances agreeing to bear out each other against all assailants; and thus linked together, with plenty of venal hands to execute their will, they were further armed by the prestige attendant upon civil and spiritual power. Holding a monopoly of civil office, they could at any time lend the smooth face of constitutional procedure to their most arbitrary acts. And as augurs and pontiffs, they possessed yet more terrible power. On a former occasion we intimated that the science of land-measuring—the power of ascertaining and regulating the boundaries of landed property—was exclusively in the hands of the augurs. The process was conducted with the same solemnities which were observed in marking out the region of the heavens for the purposes of divination, and thus had a kind of religious sanction. Superstition placed the property of all, to a certain extent, at the mercy of the college of augurs. The pontiffs, again, were intrusted with the measurement of time, and the declaring of its lapse. At the commencement of every month, the pontiff ascended the capitol, and solemnly proclaimed the event. From the obsolete Latin word *calare*, to pronounce, to intimate, was derived calend, as the name of the first day of the month. The principle upon which months were from time to time intercalated, to adjust the course of the lunar to the solar year, was known to the pontiffs alone. They were the calendar of Rome; from their declaration of time there was no appeal. At that early age, interest on loans was payable monthly in Rome; and the holders of the pontifical office were accused—nor has the accusation been very seriously rebutted—of lengthening or shortening the months and years, so as to serve the purposes of their patrician allies. Besides the terrific power over property thus possessed by the pontiffs and augurs—and the further power derived to the greater patrician houses, from their exclusive possession of the higher judicial and executive offices—the sanction of superstition was brought into play, in order to deter the ignorant many from challenging, or allowing to be challenged, the power of the patricians.

The sun never looked upon a more powerful oligarchy than that of old Rome. The natural consequence of the enjoyment of uncontrolled and uncontrollable power was tyranny of the grossest kind. The plebeians were cheated out of their hard-won share of the spoils of war; the conquered territory was parcelled out by the patricians among themselves exclusively; the poorer class of plebeians were inveigled by the specious liberality of proffered loans, and then subjected to all the tortures of the harsh Roman law regarding debtors; the patrician creditor dragged the plebeian debtor into his patrician court; and, sentence being pronounced against him, incarcerated him in his own private jail.

The plebeians had, however, several means of defending themselves. From all decisions of the consuls, an appeal lay to the *Comitia*, or assemblies of the people. And in the last resource, the plebeians, forming the main strength of the army, had it in their power in the time of war to extort concessions from their tyrants, by the simple procedure of refusing to take up arms. This was, in their constitution, equivalent to the power of stopping the supplies in our own. Both modes of bringing rulers to their senses concur in this, that they are extreme measures—calculated to convulse the state to its foundations, and therefore little likely to be adopted; in other words, little calculated to impress those in power with a fear that they can ever be used.

The Roman plebeians, however, did repeatedly avail themselves of this desperate resource. To work them up to this pitch of resolute opposition to their patricians, there were two concurring causes. The oppressions of the ruling families were becoming by degrees utterly unendurable. On the other hand, the constant accession of new citizens was daily enrolling members of the old and haughty houses of other states in the ranks of the Roman plebeians. The non-recognition of intermarriages between the patrician and plebeian houses did not infer invalidity in an unequal marriage; it merely placed the children of such marriage among the plebeians, and disqualified them from holding the higher offices of the state. Among the plebeians, there were growing up under the operation of these two causes, many aspiring spirits, who were conceiving and cherishing a discontent with institutions which precluded them from aspiring to civil distinction. The promptings of ambition in a few corresponded with the promptings of despair in the great mass. There were many plebeians equal in every respect to the patricians, but for the words of a law. There was a rooted ill-will in the great mass of the plebeians, that would have fed itself fat with the mere sight of one of their own order trampling on patrician pride. There was a better regulated conviction, that some measure was necessary to avert the enslaving of the whole plebeian body; and as usual at such crises, there was a minority of privileged *caste* coquetting with unprivileged malcontents—some from a desire to humble rival houses, others from a more generous desire to see justice done.

The three successive struggles resulted in three successive defeats of the patricians, and left at the close of the period to which we are now adverting, the plebeians in possession of tolerable securities for their liberties. The first of these was the secession to the Mons Sacer, which brought about the concession of tribunes elected by the plebeians from their own body to defend their rights; the second was the imbodying of Roman law in the twelve tables; the third was the admission of plebeians to the consular dignity.

Only sixteen years after the expulsion of the royal family, the tyranny of the patricians had reached such a height, that it could no longer be borne. A war impended over the republic, but the plebeians refused to arm. The patricians had recourse to the nomination of an officer, familiar to the constitution of all the other Latin states—a dictator. The powers of this officer were peculiarly invidious. From consular decisions an appeal lay to the Comitia: the dictator was supreme—from him there was no appeal. The only thing that palliated such an appointment was its limited duration; the only thing that made it listened to for a moment was the visibly urgent necessity. The enemy was on the march, and not an arm was raised to oppose him. The patricians skilfully selected Valerius—the most popular, the most deservedly popular, of their number. Love for him, more than fear of the powers with which he was vested, made the plebeians enlist under his banner. On his triumphant return, the senate refused to fulfil the promises they had authorized him to make—a warning often since repeated to all just and liberal noblemen, not to allow their order to make cat's-paws of them in emergencies. Valerius, in disgust, had laid down his office. The plebeians learning this, and receiving no orders to disband, inferred a plot was laid to remove them beyond the frontiers. They took up a strong position on the right bank of the Anio, a few miles from Rome, put themselves in communication with the plebeian holders of the fortified Aventine, and kept possession of the open country. The patricians elected a popular consul, and endeavoured to mollify the insurgents by promising to mitigate the laws of debtor and creditor. The people were wise, and returned an answer to this effect:—"Your consuls are not so much the officers of the commonwealth, as the heads of a faction; and, in all questions that relate to the people, are parties rather than judges. It is reasonable that we too have a head or representative in the commonwealth, under which we may act at least in our own defence." The request was granted. Tribunes were directed to be elected by the people, who might be their mouthpieces when they had representations to make; who by their acts might arrest any threatened encroachment on their recognised rights, and whose persons were declared sacred. This safeguard the people extorted from the reluctant patricians in the year of the city 260.

Still there was a wide field for oppression. The sphere of the tribunes was the public law. The private municipal law of Rome was almost entirely consuetudinary. The judge, with few and vaguely expressed laws, was left to decide on the questions submitted to his judgment, in a great measure according to his own notions of equity. There was no steady external standard by which to test his decisions. The appointment of the majority of the judges, and of the most influential among them, still lay with the patricians. Under the outer forms of justice, a world of oppression was exercised, which the tribunitial power could not control. The power confided to the tribunes, was, moreover, of a kind not easily exercised for good. They could only arrest judgment; they could not alter a bad law, or prevent the repetition of an attempt they had once defeated. Their office was an invidious one in the eyes of the patricians; they felt this, and returned scorn and hatred with equal scorn and hatred. It was rooted enmity, rather than a regard to justice, that animated both sides in the contests between the patricians and the plebeian tribunes. Their object was to distract and to punish, not to work out good; and the powers and province of both being un-

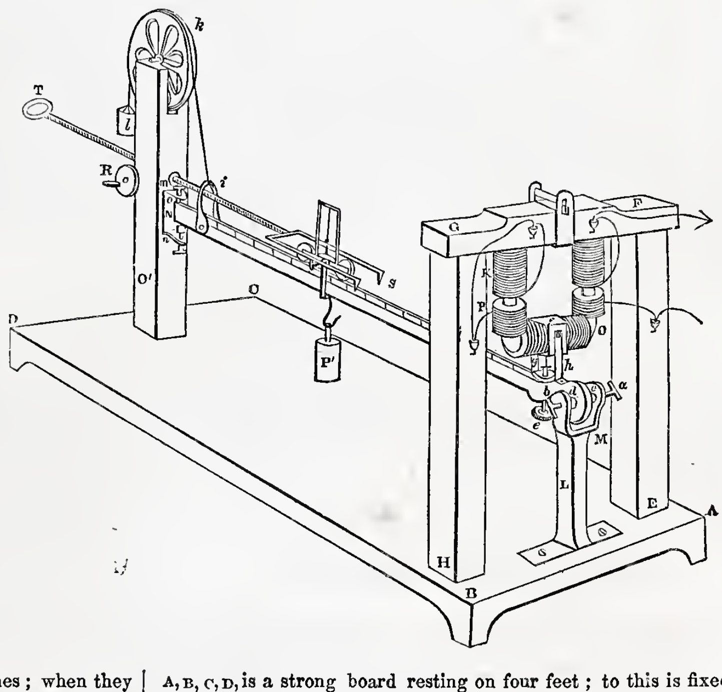
defined, there was constant opportunity of offence and recrimination. The plebeians felt themselves still too much at the mercy of the patricians. The patricians were galled beyond endurance by the contumacy of the tribunes. The result was, an ardent desire on both sides for such improvement as would give peace and security. The result was the appointment of ten men—decemvirs—to redact the laws of the republic into a concise and immutable body. The tables of laws were prepared and promulgated; the necessity of completing the code, by the addition of two more, was made by the decemvirs the pretext for soliciting a continuance in office. They were in the fair way to become the statutory magistrates of the republic; but abuse of power by one of their number brought their reign to a premature end. The republic reverted to the old cat-and-dog arrangement of patrician and plebeian magistrate yoked together and snarling at each other. But a more full and definite code of laws was the rich harvest of the experiment. From this time forth, there was less of arbitrary oppression on the part of the patricians towards the plebeians. This struggle terminated in the year of the city 302.

The next demand of the plebeians was a free career for the talent of their order in the public service. In the year of the city 308, the two tribunes of the people united in a demand, that the senate would declare plebeians eligible to the consular office. The usurpation of the priestly functions by the greater patrician houses was now brought into play, to prop up their questionable claims to a monopoly of the civil power. Not only were patricians alone admissible to the offices of augur and pontiff; the performance of certain gentile sacrifices had become hereditary in the hands of the more important *gentes* or families. It was pleaded therefore that the consul had many religious duties to perform, and these could only be performed by men of noble birth. The claims of the contending parties were reconciled by a rank evasion. The office of consul was still reserved for the aristocracy; but plebeians were declared eligible as military tribunes with consular power. It is a remarkable fact, that however harmoniously the masses may cooperate—so long as they are understood to stand all upon an equal footing—the harmony is at an end the moment it becomes necessary to give any one a marked preference over the rest. It is this which always gives the aristocratic candidate an advantage in popular elections over his plebeian rival. A man feels his self-love injured, when he is obliged to admit superior merit in one who, in every other respect, is his equal. There is no such painful feeling in giving way to one who claims precedence on the score of the accident of birth. This contemptible feeling operated on the occasion of the first election of military tribunes in Rome, as on many others. The men who had set everything on the hazard to obtain the power of electing magistrates from their own body, used the power conferred upon them, to elect a board of military tribunes exclusively consisting of patricians; and thus, as in a thousand instances, what the people had toiled and bled to obtain, they wantonly scattered to the winds the moment they got it. The patricians availed themselves of this folly to strengthen their position;—when they had popular candidates to bring forward, they proposed an election of military tribunes; when they had unpopular candidates, they contrived to secure an election of consuls. The people, tired out with their last struggle, stood idly gaping and wondering that they felt their condition in no respect bettered. They did not reflect that to possess the means to good is not enough—these means must be used. But we can scarcely blame them for their blunder in so early and rude an age; the people of France and England have not shown themselves a whit wiser in the nineteenth century of the Christian era. For forty years did the plebeians of Rome tolerate this playing at fast-and-loose (we wonder how long the patience of their later imitators will endure,) with the law permitting a plebeian to be elected military consul. Not one had yet been elected. About the year of the city 366, some individuals of wealth and high connexions succeeded in carrying their point; and raising their eyes from great to greater, aspired to the office of consul itself. Being met as formerly by the argument, that plebeians were not competent to discharge certain religious functions, they met the difficulty by proposing that the attendants on religious rites should be increased from two to ten, and that one half of the number should always be plebeians. It was evident, from the hardihood of this proposal, that however fast a hold the national creed might retain on the popular mind, men had learned to distinguish between it and the ministers of its rites. Little further objection was offered. It was ordained not merely that plebeians might be elected consuls; but that in all time coming, of the two consuls one must of necessity be a plebeian. Thus was a deathblow struck to exclusive privilege; from that moment, virtual equality, before the law, was the portion of all Roman citizens.

Thus were the outlines of a constitution developed within the walls of one city, which was subsequently to receive within its embrace the fairest portion of three quarters of the globe. How it contrived to expand—how its flexibility adapted itself to new circumstances—will remain to be shown in our next chapter.

## THE ELECTRO-MAGNETIC STEELYARD.

BY PROFESSOR M. H. JACOBI.



A, B, C, D, is a strong board resting on four feet; to this is fixed a frame, consisting of two strong posts and a cross-beam, E, F, G, H. F, G, is designed to support an iron bar, K, bent into the form of a horseshoe, and surrounded with copper-wire. It is of a paramount importance to secure this bar firmly in its position. L is a strong iron stem, divided at the top in order to receive in its two branches, the steel screws denoted by *a* and *b*. These screws are pointed, and between them moves, with very little friction, the axis *c*, *d*, of the iron lever M, N; this lever is $4\frac{1}{2}$ feet long; its upper edge is perfectly rectilinear, and fines off on each side like a sloping roof. Exactly $2\frac{1}{2}$ inches from the central point of this lever, it is made stronger, and is perforated perpendicularly, to receive a strong pin, which is fitted with tolerable accuracy, and which terminates above in a screw. Underneath,

the pin has a nut *e*, and is fastened below by a joint-piece, but above by a female screw; so that the free revolution round its axis is not prevented. The screw in which the pin terminates above, supports, as regulated by the female screw, a strong piece of brass, *f*, *g*, in which is firmly fixed the anchor, o P, surrounded by copper-wire. This piece of brass has on each side an oblong cleft, into which are introduced two corresponding connecting bars, fastened to the lever, of which one, *h*, is visible. It is evident that when the bolt is turned on its axis, the brass piece, *f*, *g*, together with the anchor, o P, surrounded by wire, may be raised or lowered perpendicularly, so that the poles of the opposite horseshoe may be brought nearer, or kept further away. The end of the lever supports a gimbal, *i*, to which is fastened a string that passes over the pulley *k*, and supports the weight *e*, which counterpoises the lever to the post o. This last supports the regulating plate. On the shoulder-piece *m*, *n*, are two adjusting screws, *o*,*p*, employed partly to keep the motion of the lever within due bounds, and partly—so far as the upper screw is concerned—to check the motion of the lever *i*; when, after the same is counterpoised, the battery circuit is complete, and the magnetic attraction takes place, before the measuring begins. P′ is a running weight that hangs on a hook, attached to a small waggon, furnished with tram-wheels, and which may be moved to and fro between the fork-like termination of a toothed rod, S, T, in which the ratched wheel R works. By means of a sliding bar (not visible in the sketch), the latter may be used as a catch, so that till then the toothed rod can be moved freely. The waggon carries a plummet suspended from a frame, which must coincide with a point that is on the waggon, in order to secure the horizontal position of the lever. For this purpose I afterward applied a level. The distance from the fulcrum of the lever to the point whence the weight is suspended is exactly 4 feet 2 inches; that is, 20 times the distance from the fulcrum to the axis of the pin, which distance has been taken at $2\frac{1}{2}$ inches. The poles of the horseshoe, as well as those of the anchor, are cylinders rounded off, so that their four extremities and the axis of the pin may be situated in a plane at right angles to the surface of the lever. This plane may be regarded as that in which the centre of gravity of magnetic attraction is situated; so that if we designate the distance of this plane, and that of the running weight, P′, from the fulcrum, by *a*, and *n a*, the attractive power, $M = n P'$. The scale on the side of the lever is divided into $\frac{1}{10}$ inches; so that, by means of an index on the waggon of the running weight, $\frac{1}{25}$th of the weight may be immediately read off, and $\frac{1}{250}$th estimated. Unfortunately the apparatus is not strong enough, in many parts, to measure any very great lifting powers. In the experiments which my colleague, M. Lanz, and myself, made with it, we confined ourselves to from 200 lbs. to 300 lbs. I may also mention that there are several circumstances which, notwithstanding the utmost precautions, affect the accuracy of observations. These, experience will point out; and I may add, that if any one would desire to perform exact experiments on the lifting power of the electro-magnet, he may advantageously make use of the instrument here described.

## DIORAMIC PAINTING.

The principles of this new art have been most admired, or perhaps rather most fully developed, in the following pictures:—*The Midnight Mass—Land-slip in the Valley of Goldau—The Temple of Solomon*—and *The Cathedral of Sainte Marie de Montréal.* Each of these paintings has been exhibited with the alternate effects of night and day gradually stealing over them. To these effects of *light* were added others, arising from the decomposition of *form*, by means of which, as for example, in the *Midnight Mass*, figures appeared where the spectators had just beheld seats, altars, &c.; or, again, as in *The Valley of Goldau*, in which rocks tumbling from the mountains replaced the prospect of a smiling valley.

*Pictorial Processes.*—The canvass is painted on both sides. In this case, therefore, whether the subjects be illuminated by reflected or refracted light, one indispensable essential is, to employ a medium or canvass which is exceedingly transparent, and the texture of which is as equal as possibly can be obtained. Either lawn or calico may be used. It is also necessary to choose those stuffs of the greatest width that is manufactured, to avoid seams, which are always difficult to conceal, especially in the principal lights of a picture.

When the canvass thus selected is stretched, it is necessary to prime it, on both sides, with at least two coats of parchment size.

*First Effect.* The first effect, which ought to be the clearer of the two, is executed on the right side of the canvass. The sketch is first made in black-lead, taking care not to sully the canvass, the whiteness of which is the sole resource possessed by the artist for bringing out the lights of the picture; for white cannot be used in executing the first effect. The colours which I use are ground in oil, but laid upon the canvass with turpentine, to which sometimes I add a little animal oil, but only for deep shadows, and these latter may be varnished without injury. The manipulation is exactly the same as in water-colour painting, with this difference only, that the colours are prepared with oil instead of gum, and applied with turpentine instead of water. It will readily occur to the artist, that he can employ neither white nor any opaque colour whatsoever by coats, which in the second effect would occasion spots more or less tinted, according to the greater or less degree of opacity. It must be the endeavour of the artist to bring out effects at a stroke—at once; going over an effect injures the transparency of the canvass.

*Second Effect.* The second effect is painted on the wrong side of the canvass. The artist, in executing this part of his work, must employ no other light than that which comes from the front of the picture through the canvass. By this means the transparent forms of the first effect are seen; these forms must either be preserved, or painted over, according to the effect intended.

First of all, a wash of some transparent blue is put over the whole canvass. This coating, like the other colours, is prepared in oil, and laid on in essence of turpentine. The marks of the brush are effaced by a huge tool of badger's skin. By means of this coating the seams also are concealed to a certain extent, by taking care to lay it on thin along the selvages, which have always less transparency than the rest of the canvass. When this coating is dry, the alterations intended to be made on the first effect are sketched out.

In executing this second effect, the artist has nothing to do beyond modelling in light and shadow, without reference to local colour, or to the colours of the first picture, which are seen by transmitted light as transparencies. This part is executed by means of a tint of which white is the base, with which lamp-black is mixed, in order to obtain a gray, the strength of which is ascertained by applying it to the wash of blue on the wrong side, and then viewing it from the right side of the picture, from which position it will not be at all perceptible, if of the proper strength. The gradation of tones is produced by the greater or less opacity in this tint. It may happen that the shadows of the first effect interfere with the execution of the second. To remedy this inconvenience, and to conceal these shadows, we can harmonize their force, by using the gray of a corresponding opacity according to the strength of the shadows which it is the intention to destroy. It will occur to the artist, that it is necessary to urge this second effect to its utmost power.

When this general effect of light and shadow is finished on these principles, and the desired effect obtained, the picture may be coloured,—the artist using only the most transparent tints prepared in oil. It is still a water colour that is to be executed; but less turpentine must be used in these glazings, which produce a powerful effect only in proportion as they are repeated several times, and with more of oil than essence. However, for slight effects of colour, turpentine is sufficient.

*The Eclairage or Lighting up the Pictures.*—The first effect painted on the right or front of the canvass is lighted by reflection; that is to say, only by a light which comes from the front, while the second effect, that painted on the wrong side, receives its light by refraction; that is, from behind only. In both effects we may employ both lights at once, in order to modify certain portions of the picture.

The light which gives effect to the painting in front should come from above. The illumination which falls upon the second effect—that painted behind, should come from vertical openings,—it being always understood that these are to be completely closed when the first effect only is to be seen.

If it happen to be necessary to modify a part in the first effect or picture by a light belonging to the second; that is, coming from behind, then this light must be enclosed so as not to fall, except on the proper place. The windows or openings ought to be distant from the paintings at least two metres,* in order to give a power of modifying the light by transmitting it through coloured media, as the exigencies of desired effects may demand. The same means are requisite for the first effect or front picture.

It is admitted that the colours which appear on objects generally are produced only by the arrangement of the molecules of these objects. Consequently all those substances used in painting are colourless: they only possess the power of reflecting such or such a ray of light which in itself contains all the colours. The more pure these substances are, the more decidedly do they reflect the simple colours; never, however, by an absolute or independent property, which by the way, it is not necessary they should do in order to represent the effects of nature.

To explain then the principles upon which dioramic paintings are executed and lighted up, take as an example the effect produced when light is decomposed; that is to say, when a portion of its component rays is intercepted.

Put upon a canvass two colours—the brightest possible—the one red, the other green, both as near as may be of the same intensity. Now, interpose a red medium, as a coloured glass, in the stream of light which falls upon them—what happens? The red colour reflects the rays which belong to it; the green remains black. Reverse the experiment by interposing a green glass—the effect also is reversed; the green colour gives forth its proper reflection; the red is now black. The effects, indeed, are not perfect, unless the interposed media completely exclude all rays but their own,—a condition not easily obtained; for, coloured media have rarely the power of excluding all but one ray. The general effect, however, is sufficiently determined.

To apply this principle to dioramic paintings, though in these paintings there are only two effects represented, one of day in front, one of night behind. These effects not passing the one into the other without a complicated combination of the media which the light had to traverse, produce an infinity of other effects similar to those which nature presents in her transitions from morning to night, and the reverse. It must not be imagined that it is necessary to employ media of very intense hues, in order to obtain striking modifications of colour; for, often a slight shade in the medium suffices to operate a very great change in the effect.

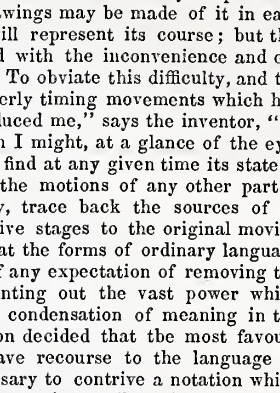
It will be understood from these principles of dioramic art in which striking results are obtained by a single decomposition of light, how important it is to observe the aspect of the sky when we would appreciate the tone of a picture, whose colouring matters are thus subject to decompositions so great. The best light for this purpose is that from a pale sky; for where the sky is blue, it is the blue tone of the picture also, and consequently its cold tone which comes out most powerfully, while its warm tones remain inactive. Their media are not present, and they are cast comparatively back into neutral tints by the blue medium of the sky—so favourable to the cold tones of the picture. It happens, on the contrary, when the sky is coloured, that the warm tones of the picture—its reds and yellows—come forth too vigorously, and, overpowering its colder tones, injure its harmony, or, it may be, give it quite a different character—a warm instead of a cold tone of colour.

It is easy to understand from these observations that the uniform intensity of colours cannot be maintained from morning to evening. We may even venture to assert it to be physically demonstrated, that a picture cannot be the same at all hours of the day. This, perhaps, is one of the causes which contribute to render good painting so difficult to execute, and so difficult to appreciate. Painters, led into error by the changes which take place between morning and evening in the appearance of their pictures, falsely attribute these alterations to a variation in their manner of seeing, and colour falsely; while, in reality, the change is in the medium—in the light.

* Between 7 and 8 feet English.

## BABBAGE'S SYSTEM OF MECHANICAL NOTATION.

In complex machines of which the parts move according to different laws, and with continually varying relations of velocity and direction, it becomes exceedingly difficult to retain in the mind all the contemporaneous movements. Mr Babbage, in the construction of his celebrated calculating machine, experienced this difficulty in common with every other mechanic engaged in working out the details of any untried piece of mechanism, involving complicated connexions and motions. By means of drawings, it is generally only possible to represent an engine in one particular state of its action; but it is often of the utmost importance to ascertain the state of motion or rest of the parts, and their directional relations to each other, under many different conditions. If the machine be indeed very simple in its operations, a succession of drawings may be made of it in each state of its progress, which will represent its course; but this rarely happens, and is attended with the inconvenience and expense of numerous drawings. To obviate this difficulty, and the "far greater difficulty of properly timing movements which had already been provided for, induced me," says the inventor, "to seek for some method by which I might, at a glance of the eye, select any particular part, and find at any given time its state of motion or rest, its relation to the motions of any other part of the machine, and, if necessary, trace back the sources of its movement through its successive stages to the original moving power." It was soon felt that the forms of ordinary language were far too diffuse to admit of any expectation of removing the difficulty; and experience pointing out the vast power which analysis derives from the great condensation of meaning in the language it employs, it was soon decided that the most favourable path to pursue was to have recourse to the language of signs. It then became necessary to contrive a notation which should be at once simple and expressive, easily understood at the commencement, and capable of being retained in the memory, from the proper adaptation of the signs to the circumstances they were intended to represent. The method adopted was not a mere hypothetical device framed to meet an imaginary difficulty: it was forced upon the fertile mind of the inventor by the actual necessity of the case, and its practicalness has been tested by its application during the construction and arrangement of perhaps the most complicated machine that was ever devised; and it answered its purpose most perfectly.




For the sake of illustration, let us examine, in the first place, with Professor Willis, the connexion of parts, and their conditions of motion, in a saw-mill. The first thing manifestly to be done is to make an accurate enumeration of all the moving parts, and to appropriate a name, if possible, to each; preserving such an order, that those parts which concur in producing the effect of any separate part of the machine may come together. Here A is a toothed wheel which may be supposed to be driven either by a water-wheel, or steam-engine, and its teeth are engaged with those of a second and smaller wheel B, on whose axis is fixed a crank e, and an eccentric E. The crank is connected by a link $c$ with the saw-frame D; this is fitted between vertical guides, and, therefore, when the crank revolves, receives a vertical oscillating motion. The timber, W, which is submitted to the action of the saw, is clamped to a carriage which moves upon rollers, $m, n$, in a horizontal direction. While the saw is in motion, as above described, the carriage and timber are made to advance in the following manner:—The eccentric E communicates an oscillating motion to a lever $e\,f$, whose centre of motion is $f$; this lever carries a

click F, which acts upon the teeth of a ratchet-wheel G, to which an intermittent rotation is thus given. Upon the axis of G is a pinion H, which, gearing with a rack fixed to the wood-carriage, causes the latter to advance towards the saw with the same intermittent motion. This intermission is adjusted to the motion of the saw-frame, so that when the saw rises, the wood shall advance, and when the saw descends, and therefore cuts, the wood shall remain at rest. The cut is made by the inclined position of the saw, the toothed edge of which is not vertical but slightly inclined forward, so as to bring the teeth into successive action during the descent of the frame. The detent K serves to hold the ratchet-wheel, and therefore the wood-carriage, firm in its position during the cut.

Now, to represent these relations and conditions of motion, rule as many parallel lines *vertically* as there are principal moving pieces in the train, and over these write the name or nature of each with its designating letter of reference in the drawing. These lines are, for the sake of reference, called *indicating lines.* Horizontal lines are then to be drawn, and in the spaces enclosed are to be written, 1st, The number of teeth on each wheel and pinion; 2d, Linear velocity of parts; 3d, Angular velocity; 4th, Comparative velocity; 5th, Origin of motion; 6th, Comparison of motion.

We may here place the table of our saw-mill complete, and then proceed to the further explanation of it.

NOTATION OF SAW-MILL.

| | Train to Saw. | | | | Train to Wood-carriage. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Names.** | Cog-wheel. | Cog-wheel. | Crank. | Saw-frame. | Eccentric. | Lever and Click. | Ratchet-wheel. | Pinion. | Rack and Wood-carriage. | Detent. |
| **Signs.** | A | B | C | D | E | F | G | H | I | K |
| **Number of Teeth.** | 96 | 22 | | | | | 60 | 20 | | |
| **Linear Velocity per minute.** | | | | | | | | | $6^{in}$ | |
| **Angular Velocity per minute.** | 11 | 50 | 50 | | 50 | | | | | |
| **Comparative Velocity.** | | | | | | | | | | |
| **Origin of Motion.** | ——> | +————————><br>+—><br> | ——> | | ——> | ...⋀.> | ——·········><br>+—> | ——> | | |
| **Comparison of Motion.** | | | | up<br>down | | | | | | holds<br>yields |

It may be here observed, that when the rectilinear motion of a part is variable, two numbers are written, one to express the greatest and the other the least. By *angular velocity,* is meant the directional velocity of all those parts that revolve: the line of some one of them may be taken as the unit of measure, or the same may be expressed in turns per minute. Again, two wheels may have the same angular velocity when they both move; but one of them may remain at rest during half a revolution of the other. In this case, their angular velocities are equal, but their comparative velocities are as 1 to 2; for the latter wheel makes two revolutions, while the other makes only one. When this is the case, another compartment is made to receive the numbers which thus arise, and is entitled "*comparative angular velocity.*"

Other compartments might be added for the pitch of wheels, adjustments, and any other particulars that may be thought necessary to keep under notice.

The compartment of the notation next given is appropriated to showing the origin of motion of each part; that is, the course through which the moving power is transmitted, and the particular modes by which each part derives its movement from that immediately preceding it in the order of action. The sign chosen to indicate this transmission of motion (an arrow) is one very generally employed to denote the direction of motion in mechanical drawings; it will therefore readily suggest the *direction* in which the movement is transmitted. As there are various ways by which the motion is communicated, the arrow is modified so as to exhibit them as far as is necessary. Our author reduces them to the following:—

| | |
|---|---|
| One piece may receive its motion from another by being permanently attached to it, as a pin on a wheel, or a wheel and pinion on the same axis. | This may be indicated by an arrow with a bar at the end. +————> |
| One piece may be driven by another in such a manner that when the driver moves, the other also always moves; as happens when a wheel is driven by a pinion. | An arrow without any bar. ————> |
| One thing may be attached to another by stiff friction. | An arrow formed of a line interrupted by dots. —·—·—·—> |
| One piece may be driven by another, and yet not always move when the latter moves; as is the case when a stud or pin lifts a bolt once in the course of its revolution. | By an arrow the first half of which is a full line, and the second half a dotted one. ——·······> |
| One wheel or lever may be connected with another by a ratchet, as the great wheel of a clock is attached to the fusee. | By a dotted arrow with a ratchet tooth at its end. ...⋀.........> |

Each of the vertical indicating lines must now be connected with that representing the part from which it receives its movement, by an arrow of such a kind as the preceding table indicates. Thus in the Saw-mill Notation, the cog-wheel A is connected with the cog-wheel B, by a plain arrow, the wheel B, upon whose axis is fixed the crank C and the eccentric E, is accordingly connected with them both by barred arrows; F with G by a ratchet-arrow; and G with K by an interrupted arrow.

The last and most essential circumstance to be represented is the succession of the movements which take place in the working of the machine. These movements are generally periodic; for almost every machine, after a certain number of successive operations, recommences the same course which it had just completed, and the work which it performs usually consists of a multitude of repetitions of the same course of particular motions.

One of the great objects of the notation in question is, to furnish a method by which at any instant of time in this course or *cycle* of operations of any machine we may know the state of motion or rest of every particular part; to present a picture by which we may on inspection see not only the motion at that moment of time, but the whole history of its movements, as well as that of all the contemporaneous changes from the beginning of

the cycle. In order to accomplish this, the compartment termed *Comparison of Motion* contains adjacent to each of the vertical indicating lines, which represent any part of the machine, other lines drawn in the same direction; these accompanying lines denote the state of motion or rest of the part to which they refer, according to the following rules, and may be called *the motion lines.*

1. Unbroken lines indicate motion.

2. Lines on the right side indicate that the motion is from right to left.

3. Lines on the left side indicate that the direction of the motion is from left to right.

4. If the movements are such as not to admit of this distinction, then when lines are drawn adjacent to an indicating line and on opposite sides of it, they signify motions in opposite directions. (*Thus in the saw-mill* A *and* B *revolve opposite ways, and their motion lines are accordingly drawn on opposite sides of their indicating lines*).

5. Parallel straight lines denote uniform motion.

6. Curved lines denote a variable velocity. It is convenient as far as possible to make the ordinates of the curve proportional to the different velocities. (*The motion of the saw-frame* D, *and of the lever and click* F, *are examples of this rule.*)

7. If the motion may be greater or less within certain limits; then if the motion begin at a fixed moment of time, and it is uncertain when it will terminate, the line denoting motion must extend from one limit to the other, and must be connected by a small cross line at its commencement with the indicating line. If the beginning of its motion is uncertain, but its end determined, then the cross line must be at its termination. If the commencement and the termination of any motion are both uncertain, the line representing motion must be connected with the indicating line in the middle by a cross line.

8. Dotted lines imply rest. It is also convenient sometimes to denote a state of rest by the absence of any line whatever. (*This rule, combined with No. 6, is employed in exhibiting the intermittent motion of the ratchet-wheel* G, *pinion* H, *and rack* I).

9. The thing indicated may be of such a nature that instead of motion it may be required to exhibit rather the periods of its being in action or out of action, open or closed, bolted or unbolted, and so on; as in the case of clicks, bolts, or valves; in which cases lines may be used in the above manner, but words must be added in explanation of this new employment of the signs. The line should be on the right side when the piece is out of action, unbolted, or open, and on the left side when in the reverse state. Dotted lines will be employed if the piece rests in both states; and if it be necessary to exhibit the time occupied by the motion of transition from one state to the other, this can be done by a short continuous line at the beginning of each; thus if a valve fly open suddenly and close gently, it will be represented as in the margin. (*The detent* K *is an example of this rule.*)

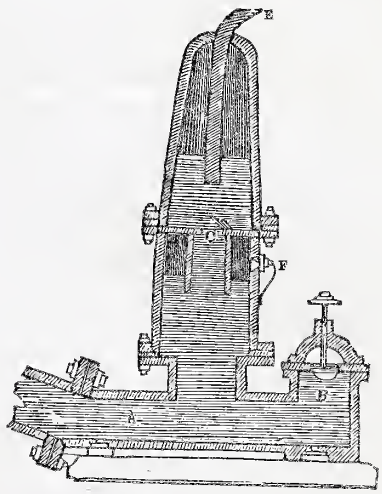
shut...... in action

open ...... out of action

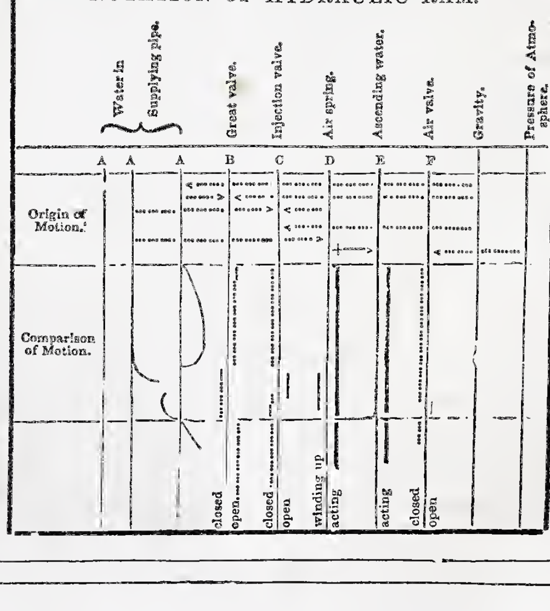
If any other modifications of movement should present themselves, it will not be difficult for any one who has rendered himself familiar with the symbols and method just explained, to contrive others adapted to the new combinations which may arise.

As an example of the way in which very minute circumstances of motion are shown in this manner, it may be remarked, that the motion of the saw-frame, eccentric, and click-lever, is necessarily continuous; but that the motion given to the ratchet-wheel by the click does not begin at the instant the change of motion in the click takes place. The click must first move through a small space until it abuts against the tooth of the ratchet-wheel which is ready to receive it. On the other hand, it is evident that the ratchet-wheel and the click will both *cease* their motion in that direction together. When the click moves backward the ratchet-wheel with the pinion and wood-carriage will remain at rest until the saw begins its cut, when they will be driven slightly backward until the ratchet-tooth abuts against the end of the detent. All these accidents of motion in the ratchet-wheel and its connected pieces are exhibited by the notation, as will appear by comparing the motion lines of G with those of F. It is true, that in the actual machine these small motions are reduced exceedingly by giving a greater number of teeth to the ratchet-wheel; but they have been exaggerated here to show the susceptibility of the notation, which when applied to complex machinery is of the very greatest service; more especially in assisting in the invention or improvement of machines.

The two machines selected by the inventor, to illustrate the application of his system of notation, are the hydraulic ram, and common eight-day clock. As the former of these may be supposed to present great difficulty in applying the method to its operations we subjoin a table of its action.




NOTATION OF HYDRAULIC RAM.



To understand the table, it is only necessary to attend to the working of the machine: the supplying water rushing along the great pipe A passes out at the great valve B; it acquires velocity until the pressure of the effluent water against the under part of the great valve causes it to close suddenly. At this moment the whole momentum of the water is directed against the sides of the machine; and the injection-valve C, being the weakest part, gives way, and admits a small quantity of water; the air-spring soon resists sufficiently to close the valve: at this moment the elasticity of the apparatus re-acting on the water in the great pipe drives it back for an instant, during which the pressure of the atmosphere opens the air-valve F, and a small quantity of air enters; this finds its way to the air-chamber, which easily discharges it through the ascending pipe, when the quantity entering is too great.

In the notation, two indicating lines A, A, are allowed to the supplying water, because it takes three different courses during the action of the machine. The first of these marks the time of its motion when it enters the air-vessel, and the second indicates its course when, owing to the elasticity of the materials, its motion is for an instant reversed, at which moment air is taken in at the air-valve F.

The notation of the clock with representations of the parts are given in the annexed plate. As in the saw-mill notation, the names are followed by the letters used to denote them. Immediately following are given the number of teeth in each wheel and pinion; next is the space for linear velocity; but this line is vacant, because almost all the motions are circular. The succeeding line indicates the angular velocity of each part; and in order to render the velocity of the striking parts comparable with those of the time part, the striking fusee is supposed to make a revolution a minute: a minute of time, that is, a revolution of the scapement wheel is taken as the unit of angular velocity. The numbers in the space entitled "Comparative Angular Velocity" express the number of revolutions one wheel makes during one revolution of some other. Thus the clock makes 78 strokes during twelve hours, or one revolution of the hour hand: if this be called unity, the pin-wheel moves through 78 pins or $9\frac{3}{4}$ revolutions in the same time; its comparative angular velocity is therefore $9\frac{3}{4}$. The space in which the origin of motion is given requires no further explanation.

The remaining part of the notation indicates the action of every part at all times; but as the whole cycle of 12 hours would occupy too much space, a portion only is given about the hour of four. As an instance of its use, let us inquire what movements are taking place at seven minutes after four o'clock. On looking down on the left hand side to the time just mentioned, we observe between the end of the sixth and end of the seventh second, that the pendulum and crutch begin to move from right to left, increasing their velocity to a maximum, and then diminishing it; that the whole train of wheels of the time part are at rest during the greater part of that second, and all move simultaneously a little before its termination. The greater part of the train of the striking part is moving uniformly; but two parts, the cross-piece and the other moving the hammer, being at the commencement of this second in a state of motion from right to left, suddenly have the motion reversed for a short time: this is at the moment of striking: two other pieces, the hawk's bill and the gathering pallet, appear to act at the same moment.

Let us now inquire into the source of motion of the minute hand. On looking down the space in which the origin of motion is given, we observe an arrow point which conveys us to the cannon pinion with which it is connected permanently. The cannon pinion is driven by the centre or hour wheel, with which it is connected by stiff friction. The hour wheel again is driven by its pinion to which it is permanently attached. The hour wheel pinion is driven by the great wheel into which it works; the great wheel is driven by the fusee with which it is connected by a ratchet; and the fusee is driven by the spring barrel or main spring, which is the origin of all the movements.

These illustrations are sufficient to render the notation intelligible, and to point out its importance to the practical mechanic. One of its best recommendations is its universality: the symbols employed are few and simple; and to those who become skilful in their use, they furnish the means of writing down at sight even the most complicated machine, and of understanding the order and succession of the movements of any engine of which they possess the drawings and mechanical notation. In contriving machinery, in which it is necessary, that the numerous wheels and levers, deriving their motion from distant parts of the engine, should concur at some instant of time, or in some precise order, for the proper performance of a particular operation, it furnishes most important assistance.

## ON THE DISTINCTIVE CHARACTERS OF ANIMALS.

### CHAPTER II.

Let us now glance over the animal kingdom, and compare the various kinds it contains with one another.

I. In point of *size*, animals differ widely from one another. The existence of some is known only by a powerful microscope, while the length of others exceeds a hundred feet, and their weight as many tons. These extremes include animals of every intermediate bulk.

II. The *forms* assumed by animals are infinitely varied, and present many interesting particulars for investigation. Some of the lowest present themselves under the likeness of a globule, of a filament, or of a flattened membrane, and some have no uniform or regular shape. Those which exhibit a determinate form, have their parts either arranged round a centre, or consist of two similar halves, cohering in the middle. The former are the radiated, the latter the symmetrical animals.

III. With regard to *structure*, of course the amorphous animals, at the bottom of the scale, are the most simple of all. The bodies of some of these are without any internal cavity, which we have some time back mentioned as the circumstance most characteristic of an animal; and they are considered to be animals, principally on account of their powers of rapid motion.

In the radiated animals, the organization becomes more complicated. We find a digestive cavity, sometimes with two openings, a mouth and anus, sometimes with only one, serving for both purposes. Through the walls of this cavity, the nourishing fluids infiltrate, and make their way through the general mass of the animal's body. In this class we also discover the rudiments of the nervous and muscular systems. The nervous system consists of rounded masses of a white soft substance, equal in number to the rays composing the animal, connected together by slender white cords, and sending off filaments to all parts of the body. The muscular system consists of reddish and whitish fasciculated fibres, disposed in bundles along the rays. Their external surface is the only organ of respiration which they possess.

The three systems now enumerated, the digestive, the nervous, and the muscular, are readily demonstrated in the majority of the symmetrical animals; and are very soon found to become complicated, and to have many other parts and organs superadded to them. The digestive apparatus consists of a mouth for the taking in of aliment, a stomach for its commixture, an intestinal canal, from which the nourishing juices are absorbed, and an anus from which the undigested residue is expelled. Whilst in the radiated division, the nutritious fluids were assimilated only by imbibition; in the symmetrical animals we find vessels, the rudiments of a circulating system, employed in receiving the juices prepared in the digestive apparatus, and transmitting these to all parts of the body. Digestion in this class becomes a more complicated process, and various fluids, particularly *saliva* and *bile*, the products of large special organs, are added to the alimentary mass during its progress.

In addition to the digestive apparatus and general external respiratory surface, we by and by find an especial system dedicated to the aëration of the juices prepared for nutrition; this is the *respiratory apparatus*. It is of extreme simplicity at first, being only a fold of the integument turned inward, so as to form a simple cavity or sac within the body. As we ascend, we find it rendered more complex, becoming a *trachea* or *wind-pipe*, branching through the body, or it is confined to a particular division of the trunk, and denominated *lungs* or *gills*, according as it is fitted to receive the atmospheric air immediately, or to make use of that portion of air which is suspended or dissolved in the water.

The existence of this separate respiratory apparatus supposes a greater perfection of the *circulating system*. The fluids, prepared by the organs of digestion, require exposure to the air in lungs or gills, and wherever these exist, there must be a modification of the heart or arteries, to convey the blood to them, and after its purification, to distribute it all over the system. Besides, there must be conduits to return the blood which has not been expended,—the veins; and another system of vessels, to remove the worn-out parts,—the lymphatics. For the purification of the circulating fluid, we have, in addition, certain glandular organs, of which the most useful and most generally found are the kidneys.

As we ascend in the scale of animals, we find the *instruments of sensation* becoming gradually more and more numerous, and the *nervous* system more and more complicated. At first it is found consisting of a series of *ganglia*, with threads of communication, and nerves supplying the organs of sensation and motion; then it has a central part added, from which the special nerves go to the organs of the senses. In the more perfect animals, this central part is the brain, with its prolongation, the spinal marrow. In these also we have in addition to, or rather separated from, the central system, nerves which before were conjoined with it, termed the sympathetic or visceral nerves, under whose direction the processes of nutrition and secretion, or of organic life, are carried on.

In intimate connexion with the functions of animal life is the *muscular system*, the agent of locomotion. At first it is exceedingly simple, and operates at great disadvantage from the want of levers and points of support, as in the molluscous animals; but by and by, as we ascend, we find it provided with a *skeleton*, or frame-work, by means of which it operates to the best advantage. The skeleton may be either external, and horny; or internal, and osseous. In the first case, as in the lobster, the muscular system is enclosed *within* the resisting pieces which it has to move; in the second, as in the vertebrata, it is arranged *round* them. The bones and muscles together form the various instruments with which animals accomplish the dictates of the appetites, instincts, and propensities. They form hands, feet, fins, jaws, wings and the tail for catching, or striking. Besides, the muscular system with the bony, and the cartilaginous, compose the most universal instrument by which animals communicate to each other their proximity, their wants, their dispositions, namely the *larynx*, or *organ of voice.*

Having now gone over the various functions which distinguish animals, let us glance at them again, to notice this time, not their general characters, but those *differences in structure*, for the performance of function, rendered necessary by the *peculiar habitudes* which nature has assigned them.

1. The assumption of food from without, we have seen, is at first so simple, that the term *imbibition* sufficiently expresses it; and here no very evident structure for its performance can be detected. As we ascend, we find a cavity, having first one opening, then two, one for receiving and the other for rejecting, and we gradually find connected with it an apparatus for bruising the food, for mixing it with saliva, for macerating it in a crop, or in a series of pouches, mixing it with bile, pancreatic, and gastric juices, and transmitting it along a canal, four, six, or ten times, the length of the body to which it belongs.

2. Absorption, or the taking up of matter into the vessels, is of several kinds, in all animals except the lowest. Absorption takes place from the digestive canal, by means of the lacteal vessels, which suck up the milky chyle formed on the surface of the food, and carry it into the veins near the heart. The fluids which are poured into internal cavities having no outlet, the serum and the synovia, are removed by the lymphatic vessels, and by them many of the secreted fluids, the bile for instance, and the spermatic fluid, are inspissated and rendered more fit to accomplish the ends which they are intended to serve. Besides, absorption is intrusted with the removing from the body those particles which have remained so long in it, as to be no longer capable of performing their share of its functions, and this species of absorption is performed by the lymphatic vessels, and probably also by the veins.

3. Intercourse with the atmosphere appears to be essential to every living thing, and we may be prepared to expect great variety in the mode by which it is established. Among the inferior tribes, which are nourished by absorption immediately from the surface of the body, we may presume that the matters absorbed have either undergone the needful changes before they are taken into the body, or that these changes take place at the time they are appropriated. In animals, digestion of the food takes place previous to its assimilation. It is evident that aëration could not be performed in the bowels, and hence the necessity for *respiration.*

We have already observed that respiration is accomplished in two very different ways. In some classes there is a number of holes arranged along the sides, from which air-tubes are distributed through every part of the body. The air in these creatures is evidently brought into communication with the nutrient juices, *when they have already arrived at their destinations;* and the necessary changes are wrought upon them at the instant of their assimilation. In other classes again, there is a special apparatus, the lung or gill, where the air has access to the nutritive fluid, previous to its final distribution.

There is another modification of the function of respiration, according to the media in which animals live. Those who live in air, breathe it immediately; those who live in water, breathe it mingled with, or dissolved in, the surrounding element. Those who breathe by means of tubes proceeding through their whole forms, have these tubes filled with air or water, according as their residence is in the one or the other; those who have a special organ for the purpose, have it modified according to the medium in which they live; if in air, the lung is a bag, or series of bags, into which the air is sucked; if in water, it is a gill, or organ composed of many branches, over and among which the water is allowed to run freely. Quadrupeds and birds breathe by means of lungs; fishes and the molluscæ by means of gills. In certain reptiles, which are the true amphibious animals, there are both lungs and gills, to be used when the creatures are in air or water respectively.

4. A *circulation*, properly so called, is found only in animals considerably raised in the scale of creation. As it signifies a progressive motion of the nourishing fluid, it can take place only when such a fluid exists. This fluid passes from the centre, over the body, through a series of canals: a part of it is appropriated to the nutrition of the parts through which it passes, and then the rest of it returns to the centre from which it set out, to be again distributed. It is at this point that respiration is needed, to remove impurities, and to impart vitality, before the blood is again sent out.

In some classes, we find the circulation performed by vessels only,—the arteries, or some part of them, being possessed of a contractile power. In others, we find, in addition to the arterial tubes, a forcing pump or syringe called the heart. This, in its simplest form, consists of two chambers; one for receiving the blood brought by the veins from the extremities of the arteries; and the other for the active duty of forcing it on through these. It is not necessary for me here to enlarge upon the different forms of the circulation,—the double heart, and so on; all this would require much discourse and many illustrations.

5. *Assimilation* appears to be identical in all animals; it is the conclusion of nutrition,—the appropriation of the nourishing fluid; and however varied the apparatus that ministers to the act, we may presume that the act itself does not essentially differ in one animal from what it is in another.

6. After assimilation we have *secretion*, a function which offers extensive differences in every province of the animal kingdom. It consists in the separation of certain matters from the blood, or circulating fluid. It is generally spoken of as of two kinds, *excretion*, and *secretion* properly so called. In the lowest tribes, excretion is very simple,—consisting of a mere exhalation from the surface of the body. In the more elevated, we find another and very important excretion superadded, namely, the *urine.* Besides, we find various fluids formed from the general circulating mass, subservient to important ends in the economy. Such are the *bile*, the *saliva*, the *synovia* of the joints, and the *spermatic fluid.*

7. All animals possess *sensibility* or *sensation*, though in very dissimilar degrees; and besides the capacity of receiving impressions, we find them in general to have the power of reacting on surrounding bodies. With regard to the external senses, animals differ immensely. Some have only the sense of touch; others in addition have taste and smell; and the more perfect possess also sight and hearing. The internal senses, as they have been called, or sensations of wants, also differ very much. First stand hunger and thirst, prompting to the taking of food; then comes the necessity for air, prompting to respiration; then the feeling, prompting to the act of reproduction, and so on.

Then we come to see in different animals different *propensities* or *instincts*, leading to the performance of various acts necessary for their various modes of life. Rising still higher, we find something like moral faculties, in virtue of which some animals are generous in their nature, some rapacious, some cautious or cowardly, some persevering or obstinate. When we pass on to consider man, we find that the distance is immense, the boundary impassable, the demarcation between him and all other creatures, impossible to be mistaken. He alone is possessed of *mind*, that endowment in virtue of which he has been made by the Almighty the master of creation.

8. Locomotion is a function so evidently in relation with the circumstances in which animals exist, and the apparatus with which they are provided, that it is not necessary to say more than has been already done, on the means by which it is accomplished.

9. Finally, in addition to the acts by which the individual is preserved, there is a very interesting series by which the species is continued. In the lowest grades, this is accomplished without the concurrence of the sexes. At a determinate period of its life, an animal splits or separates into several fragments, which become so many new and independent individuals, or it throws out buds either from its outer surface, or from an internal cavity.

A little higher, we find reproduction taking place by two sets of organs, divided between different individuals, who are said to be of opposite *sexes*. When the male and female organs are united in the same individual, it is denominated a *hermaphrodite* animal, and in some cases seems to suffice for its own impregnation; but more generally, hermaphrodite animals are not capable of performing this act upon themselves, but require the concurrence of two similar individuals, who meet, and reciprocally impregnate each other.

Among the more perfect classes of the animal kingdom, the organs of reproduction are always allotted to two different individuals, *males* and *females*. The fecundating fluid of the male is applied to the germs furnished by the female, either while they are within her, or after they have been deposited. In the after part of the process, we have the following varieties. The egg or germ is expelled from the body of the female, and is matured after a certain time, under the influence of a certain temperature, when the young creature bursts forth, and commences its independent existence. Such animals are *oviparous*. Or the egg takes such a long time to pass from the ovary where it was formed, that the young one is hatched before it can escape, so that it gets alive from the body of its mother. These animals are called *ovo-viviparous*. In a third class, the egg passes from the ovary into a reservoir fitted for its reception—the womb, or uterus—where it grows at the expense of the mother, and is at length expelled in a state so perfect as to be able to live by itself. The classes in which this mode of reproduction obtains, are the highest of all, including quadrupeds and man, and are said to be *viviparous*.

Here the work of reproduction properly ends; but the young are so generally born in some sort so immature, that the connexion between the offspring and the parent does not cease immediately. In the class of mammalia, indeed, the connexion is little less intimate,—the young creature still depending on its mother for the nourishment which it draws from her breasts, for the warmth it requires, and the protection it needs till able to provide for itself.

# ASTRONOMY.

## CHAPTER I.

### INTRODUCTORY REMARKS.—EARLY HISTORY OF ASTRONOMICAL DISCOVERY.

It has often been remarked, that the enlightened student of every branch of natural science imagines that, of all the other parts of this science, that which he pursues is the best calculated for the moral and intellectual improvement of man; the more he studies, the more he will feel assured, that to annihilate the least tendency to scepticism, we have merely to follow him in his department of study to behold proofs the most undeniable, and evidences the most convincing. Take, for example, the intelligent student of botany, the student of natural history, of chemistry, of physiology, of geology, of astronomy—each of them is deeply impressed with the conviction, that his favourite department of science is the most replete with wonderful instances of the adaptation of means to ends—that it alone is capable, when studied with a becoming spirit, of raising the mind from the effect to the cause, from " nature up to nature's God."

The botanist points to the wonderful provision by which different species of plants can disseminate themselves over the globe. Some seeds are provided with wings, to be wafted afar by the breeze, others are carried to distant spots by the fowls of heaven, while others are scattered by the river stream and the ocean current. The naturalist points with exultation to the beautiful adaptation of every species of animal to the food on which it is intended to live, to the country in which it is found, and to its place in the scale of animal life. In Lapland, where our domestic animals would starve, the reindeer, which could not exist in a more southern clime, thrives upon tufts of moss, and constitutes almost the sole subsistence, comfort, and wealth, of the inhabitants of that dreary region. The camel is to the Arab what the reindeer is to the Laplander; with broad flat hoofs formed for travelling upon sand, with a peculiarly constructed stomach, enabling it to contain food and drink for several days, it can accomplish lengthened journeys over a desert which to all other animals would be inevitable death. Without the help of the camel, the native of Persia, of Arabia, of Barbary, or of Egypt, could neither subsist, traffic, nor travel.

The chemist, the physiologist, and the geologist, all put in their claims for *their* sciences being considered the most elevating pursuits for the human mind; but each gives way to the astronomer, who makes his appearance with, it may be, a pale countenance and thoughtful aspect, from his sleepless nights and mental toil, but there is fire and energy in his eye, intelligence beams on his brow, the grosser passions of human nature seem to have died within him, and his words breathe the aspirations of an elevated soul. He is not tied to earth like common mortals, he dwells in regions far beyond the sun, his habitation is the mighty orbs that people the infinity of space. Need we wonder, says he, that the science of astronomy was the first to attract the attention of mankind? Need we wonder that our ancestors imagined that some mysterious connection existed between the stars and the earth, and that the destinies of individuals and of empires were ruled by the heavenly bodies? Need we wonder that the sun, the most splendid object visible to the senses, should be looked upon by poor benighted creatures as worthy of divine adoration—being, even in more enlightened ages, considered a fit emblem of the source of all light? What can expand or elevate the mind more than the study of the heavens, whose essence is expansion, upon a scale inconceivably grand—whose nature is elevation, to an extent far beyond the reach of thought?

Behold the sun! that glorious and resplendent orb, the centre of our solar system, the great source of life, and light, and heat, to our otherwise uninhabitable world; he appears no larger than the moon to the naked eye, but his size is one and a half million of times that of our earth, and seventy millions of times the size of the moon. It will give a better idea of his enormous magnitude when it is stated, that the distance between the earth and the moon being 238,000 miles, it would take nearly *four* times this distance to measure his diameter. Let us carry our imagination far beyond the sun, and behold the planets of our system rolling at various distances, and with different degrees of velocity in their respective orbits around him. (See plate, Solar System.) Nearest is the planet *Mercury*, only one twenty-fifth part of the size of our globe, 37 millions of miles distant from the sun, flying around him at the tremendous rapidity of 111 thousand miles per hour, and completing its annual revolution in nearly 88 days. Next is *Venus*, our beautiful morning and evening star; its size is about four-fifths that of the earth, its distance from

# COMPARATIVE MAGNITUDES OF THE PLANETS

The Comparative Diameter of the Sun upon this Scale will be Two feet four Inches

JUPITER
Diameter 89 000 Miles

SATURN
79 000 Miles

NEPTUNE
50 000 Miles

URANUS
35 000 Miles

EARTH 7.912

VENUS 7.800

MARS 4.189

MERCURY 3.140

MOON 2.180

## RELATIVE DISTANCES OF THE PLANETS FROM THE SUN.

MILLIONS OF MILES

| 37 | 68 | 95 | 142 | 490 | 900 | 1800 | 3.200 |
|---|---|---|---|---|---|---|---|
| MERCURY | VENUS | EARTH | MARS | JUPITER | SATURN | URANUS | NEPTUNE |

A Cannon Ball flying at the rate of 1000 Miles an hour, would take to reach the Sun from Mercury 4½ Years, Venus 8 Years, Earth 11 Years, Mars 16½ Years, Jupiter 59½ Years, Saturn 102 Years, Uranus 205½ Years and Neptune about 350 Years.

the central orb is 70 millions of miles, its rate of travelling more than 80 thousand miles per hour, and it takes $224\frac{2}{3}$ days to complete its yearly circuit. The third place is occupied by our *Earth*, with its attendant *moon*, at the distance of 95 millions of miles from the sun, rolling around him at the rate of more than 68 thousand miles per hour, and accomplishing its annual revolution in $365\frac{1}{4}$ days. The small planet *Mars* occupies the fourth place, about one-fifth the size of our earth, at the distance of 146 millions of miles from the sun, travelling at the rate of 57 thousand miles per hour, and performing its annual circuit in 686 days 23 hours. Between Mars, and the next large planet, Jupiter, have been discovered a number of small planets, called *Asteroides*—*Vesta*, *Juno*, *Ceres*, *Pallas*, and six others; from 225 to 267 millions of miles from the sun, accomplishing their circuit around him in from $3\frac{1}{2}$ to $4\frac{1}{2}$ years: Pallas, the largest, being one fifty-fifth part of the size of our earth, Vesta only one twenty-five thousandth, while others are much smaller. They travel at various velocities, from 46 to 42 thousand miles per hour. *Jupiter*, with his four attendant moons, occupies the next place—by far the largest planet of our system, more than thirteen hundred times the size of our globe, at the distance of 485 millions of miles from the central luminary, travelling at the rate of nearly 29 thousand miles per hour, and requiring almost 12 years to complete his revolution round his mighty orbit. The beautiful planet *Saturn*, with his rings and seven satellites or moons, next arrests our view; at the distance of nearly 1000 millions of miles from the sun, and more than a thousand times the magnitude of our earth, it travels at the rate of 22 thousand miles per hour, and takes $29\frac{1}{2}$ years to accomplish its extended circuit. Far beyond the orbit of Saturn, invisible to the naked eye from our globe, 1800 millions of miles distant from the sun, we find the planet *Uranus*, attended by six moons; its size is eighty times that of our earth, its rate of travelling is 15 thousand miles per hour, and it does not complete one revolution round its orbit in less than 84 of our years. Extending our gaze 1200 millions of miles beyond the orbit of Uranus, at the tremendous distance of 3000 millions of miles from the sun, we see, with a telescope, another planet, *Neptune*, attended by several moons, 125 times the size of our earth, travelling at the rate of more than 13 thousand miles per hour, and requiring 164 of our years to complete one of its mighty revolutions round our central luminary. The distance of the planet Neptune from our earth is so great, that we can form no accurate conception of it in our minds—2905 millions of miles! Light, which travels at the rate of 12 millions of miles per minute, would take more than *four* hours to reach us from that far distant planet; and a railway carriage, travelling day and night at the rate of 30 miles per hour, would take more than 10 thousand years to accomplish the same journey. This appears to be the frontier planet of our system, and at its enormous distance from the sun, that orb would appear to our vision no larger than one of the stars. (See plate.)

This great scheme of globes, moving round the sun in various periods, and at various velocities, is called the *Solar System*—from *sol*, the Latin for sun. To our limited comprehension, it is built upon a magnificent scale; but what is it, compared to the innumerable multitude of systems around it;—the millions of stars—all suns, most of them much more glorious than our own—each the centre, perhaps, of a system on a far grander and much more extended scale than the one we have been contemplating? The distance from our sun to the planet Neptune is great, but how it dwindles to a point when we compare it with the distance from the earth to the nearest fixed star! More than 60 millions of millions of miles distant, upwards of sixty-three times the size of our sun, do we behold the star *Sirius*, a mere spark in the distance. Its light, travelling at the rate of 12 millions of miles per minute, would not reach us in less than *ten* years; and were that star at this moment annihilated, it would take that length of time before its last ray of light would cease to reflect its image in the eye of the astronomer, so as to make him aware of its non-existence. Let us take our stand now upon this fixed star, and lo! our sun is lost in the distance, his rays are invisible to the unaided eye! And what do we see? Are the other fixed stars increased in size from our greater proximity? No; not only are these bodies placed at these enormous distances from our system, but they are at as great distances from each other; so that a star of the second magnitude is at as great, if not a greater, distance from a star of the first magnitude, as the latter is from our globe. Where, then, is the termination of these luminous orbs? Were we to traverse space a thousand times farther than the nearest fixed star, the same endless succession of millions of suns and systems would meet the eye of the astonished beholder. Are these, then, scattered in endless profusion through the unfathomable depths of limitless expanse? No; *our* universe of suns and systems has a limit: its breadth has been measured, and its depths have been sounded. Space has been defined to be a circle, whose centre is everywhere, and its circumference nowhere; through this boundless infinity, the telescope discovers universe after universe in endless succession, at distances from each other appalling to the imagination; and were we placed on some planet in the nearest universe to our own, we would see, only through a powerful telescope, *our* universe of suns and systems a mere cluster, and their distances of 60 millions of millions of miles from each other contracted to a point. There it hangs! a mere handful in the eyes of its Almighty Creator! one *cluster* (fig. 1) among myriads that people the infinity of space!

What a field for contemplation does this open up! what a lesson of humility! What is *our* globe, once supposed to be the great centre of the universe, but like the smallest grain of dust among the sands of the sea-shore, when compared to the astounding works of God!

This, then, is a faint glimpse of the wonders opened up by the study of astronomy—a bird's-eye view of the ground we mean to tread; and if we enter on our pursuit with minds deeply imbued with the grandeur of the theme, giving it our undivided attention and thought, accepting with becoming modesty the splendid results which have been attained by the efforts of genius in our own and other countries, at the end of our journey our minds will be expanded, our thoughts elevated, and our ideas will flow in a purer channel.

Do not think that this is a useless study; that the time spent in acquiring a knowledge of it is time wasted; that astronomy ought to be left for those who have leisure and learning to enable them to follow such unprofitable pursuits. Listen to the sentiments, on the acquisition of scientific knowledge, of the most distinguished and enlightened statesman of our age; one, than whom none had the best interests of the great human family more at heart, the patron of literature, the promoter of science, the protector of art, and the friend of oppressed genius—the late lamented Sir Robert Peel. In his inaugural address at the opening of the Tamworth Institution, in 1841, he spoke as follows:—"Heed not the sneers and foolish sarcasms against learning, of those who are unwilling that you should rise above the level of their own contented ignorance. Do not for a moment imagine that you have not time for acquiring knowledge; it is only the idle man who wants time for everything. The industrious man knows the inestimable value of the economy of time, and, amidst the most multifarious occupations, can find leisure for rational recreation and mental improvement. Do not believe that the acquisition of scientific knowledge will obstruct your worldly prosperity, or that it is incompatible with your worldly pursuits. Rely upon it, you cannot sharpen your intellectual faculties, you cannot widen the range of your knowledge, without becoming more skilful and successful in the business or profession in which you are engaged."

The diffusion of scientific knowledge among the labouring population of Britain, during the last quarter of a century, has been so extensive, that it might be supposed it would be difficult to find an instance, at the present day, illustrative of the notions of the ancients respecting the form and relative position of the earth, and the motions, distances, and

magnitudes of the heavenly bodies. A short experience, however, in a remote country district would soon lead to the discovery that the majority of its inhabitants are still unable to separate apparent motion from real motion, apparent size from real size, or apparent distance from real distance; that they still look upon the earth as a flat plain at complete rest, occupying the centre of the universe, while the sun, moon, and stars perform their daily revolutions around it. How this takes place, how the changes of the seasons and various other phenomena are produced, never occupies their minds for an instant. They may have heard that the earth is round, that sailors have circumnavigated the globe; but they imagine it must have been round the flat surface on which we live, for they cannot conceive how people could stand on the opposite side of a round globe with their feet to ours, without falling off. They may have also heard that it is the interposition of the moon between us and the sun that causes eclipses of the sun, and the interposition of the earth between the sun and the moon that causes eclipses of the moon; that the earth revolves round its own axis in twenty-four hours, producing day and night, and round the sun in a year, effecting the alternations of the seasons. But all these truths are so far from being fixed in their minds, that they look upon them with much less certainty than doubt. With the calendar, to divide and measure the year, made to their hands; with clocks and watches, to measure the hours of the day and night; with religion, to tell them that the stars have no influence over worldly affairs; they have by no means the same inducements which the ancients had to devote their time and attention to the study of the skies; and this may partly account for their being in total darkness regarding the simplest truths of astronomy, while the light of knowledge shines around them wit the brightness of meridian splendour.

At a very early period of the world's history, its inhabitants must have begun to observe and to note the various phenomena of the heavens. The pastoral life they led, tending their flocks through the midnight watches, the serenity and purity of the atmosphere of eastern climes, must have soon directed their attention to the different changes in the appearance of the moon, and to the risings and settings of the stars. By these they traced their footsteps in the pathless woods and lonely moors—by these they watched the deadly approach of the midnight enemy—by these they marked the long silent hours of the dreary night, and hailed the appearance of the morning star as the welcome harbinger of dawning day. The moon would be to them an object of peculiar concern; they would watch her various phases with unceasing interest, mark her different periods with unerring accuracy, and wish that the full moon would continue always to shed her mellow splendour over their lonesome night. They would count the days from new moon to new moon, and from full moon to full moon; and, appalled with horror, would they behold her darkened in dim eclipse, and tremble lest some awful calamity should befall the world. Her eclipses would be noted with the greatest care; and, by lengthened observation, they would discover, in course of time, that during a period of $6{,}585\frac{1}{3}$ days, which comprises 223 new moons and 223 full moons, the moon would complete all her possible variety of changes and eclipses; and that, in every succeeding period or cycle of this duration, these lunations and eclipses would regularly recur on the same days as they did in the previous cycle. To this period they gave the name of *Saros.* It was said to have been discovered by the Chaldeans, and it was known to almost all the ancient nations, enabling them to predict eclipses of the moon with tolerable accuracy.

No sooner would mariners have begun to trust themselves in their frail barks, and to brave the stormy sea, than they would search for some fixed point in the heavens to guide their path through the trackless ocean. Thus would the *North-pole Star* be discovered, by the aid of which the Phœnicians are said to have circumnavigated Africa at a very early date, sailing down the Red Sea, and landing at Alexandria after an absence of three years.

When the art of agriculture began to occupy the attention of the world's increasing inhabitants, a new inducement was added to the study of the phenomena presented by the heavenly bodies. The height or altitude of the sun at midday; the risings and settings of the various groups of stars, called *constellations,* would divide the different seasons of the year, and tell them when to till the ground and prepare for seed-time, when they ought to sow, and when the harvest ought to crown their labours with abundance, and secure them against famine for at least another year.

In measuring the hours of the night and the seasons of the year by the risings and settings of the stars, these primitive observers would discover, by watching the different stars as they were absorbed in the rays of the morning sun, or were the first to appear at his point of setting in the evening, that a daily revolution of the stars did not correspond *exactly* to a daily revolution of the sun; that he required a few minutes longer to accomplish his circuit than they did; that he would thus daily change his place among them by falling back a little, and, at the end of $365\frac{1}{4}$ days, that he would just be in the same place among the stars as at the commencement of this period, having completed a whole round of the heavens, *backward,* as it were. To the sun's path in the heavens on the day of the spring or autumn solstice, when day and night are equal, they gave the name of the *Equinoctial line,* or the line of the equator; to his *backward* path among the stars, requiring $365\frac{1}{4}$ days to complete the circle of the heavens, they gave the name of the *line of the Ecliptic,* from the circumstance that eclipses *only* occur when the moon, in her path in the heavens, happens to cross this line, either when new or full, in such a manner that the sun, moon, and earth are in a straight line (fig. 2).

By continued observation, they would also note that a few of the stars did not keep pace with the others in their apparent motion from east to west, but would sometimes fall behind, and at other times would move faster onwards, as if to make up their leeway; these were called "*planets,*" —from the Greek word πλανητης, *a wanderer*—in contradistinction to the other stars, which were called "*fixed stars,*" from their always keeping the same relative position amongst each other. That the five planets—*Mercury, Venus, Mars, Jupiter,* and *Saturn*—must have been discovered at an early age, is proved from their names being given, along with those of the *Sun* and *Moon,* to the seven days of the week by all the ancient nations, Egyptians, Chaldeans, Indians, Chinese, and even by the Druids in our own country; and this, too, at a period so remote as to be lost in the mists of fable. The same order of the days was not preserved among the different nations; but this is only additional evidence of the antiquity of the adoption of the week as a measure of time, and the naming of its different days. Our Sunday corresponds to the Saxon *Sunnadæg,* or day of the Sun; Monday, to *Monandæg,* or day of the Moon; Tuesday, to *Tiwisdæg,* or day of Mars; Wednesday, to *Wodensdæg,* or day of Mercury; Thursday, to *Torsdæg,* or day of Jupiter; Friday, to *Frigdæg,* or day of Venus; Saturday, to *Sæterdæg,* or day of Saturn.

What nation was the first to direct its attention to astronomy, is now no less a useless than a fruitless inquiry. The Chaldeans, Indians, Egyptians, and Chinese, have each had their advocates in awarding them the palm of priority of observation and discovery in astronomical science. We are told, though upon questionable authority, that when Alexander the Great captured the city of Babylon, 331 years before the Christian era, Callisthenes, the philosopher who accompanied him, collected astronomical observations of the Chaldeans for a period of 1903 years, and that, by the command of Alexander, he transmitted them to Aristotle. There can be no doubt, however, that they accurately observed and noted eclipses of the moon 720 years before Christ. They knew the cause of solar eclipses, and they understood dialing, as is shown from their sending, in the seventh century before Christ, to King Hezekiah, to inquire concerning the retrogradation of the shadow on the dial of Ahaz.

The Egyptians, from observing the times of the star Sirius emerging from the rays of the sun, fixed the length of the

year at 365¼ days. They are said to have observed and noted eclipses of the sun and moon, to have known their causes, to have been acquainted with the spherical form of the earth, and with the revolutions of Mercury and Venus round the sun, from a very remote period. They certainly were able to predict eclipses of the sun, although with no pretensions to accuracy.

Although astronomy never rose to the rank of a science among the Chinese, it was held in such repute among them, that it is said to have been cultivated by their king 2752 years before the Christian era, and that the crown of China was awarded to an individual on account of his knowledge of astronomy. At that early date, they discovered the Metonic cycle of nineteen years, the North-pole star, drew out directions for the calculation of eclipses, and even constructed a catalogue of 2,500 stars.

The Indians lay claim to a series of astronomical observations, extending to 753 years before the flood of Noah, or only 28 years after the death of Adam. Some individuals of great learning have advanced much reasoning and argument to make this claim good; such as the celebrated M. Bailly, in France, and the late Professor Playfair, in Scotland; but, in the opinion of most astronomers of the present day, this date is apocryphal.

The Grecians received their knowledge of the rudiments of astronomy, as they did of almost all their other sciences, from the Egyptians and Phœnicians. About the thirteenth or fourteenth century before Christ, their attention appears to have been directed to the study of the heavens; but that early age is so involved in mystery and fable, that it is impossible to ascertain the state of the science, or even the names of its cultivators.

From the middle of the seventh century before the Christian era, however, down to the beginning of the fifth, many illustrious philosophers flourished in Greece, several of whom devoted themselves almost exclusively to the study of astronomy. By travelling over Egypt and the East, they acquired a knowledge of it as far as could be learned among these nations; and, returning to their native land, established schools for its promotion and diffusion among their countrymen. The most celebrated of these teachers of astronomy were Thales, who founded the Ionian school, and Pythagoras, who, on his return from the East, being received coolly by his countrymen of Samos, went to Italy and founded the celebrated school of Crotona. The most distinguished disciples of these two great masters were, Anaximander, Anaximenes, Anaxagoras, Philolaus, Meton, and Democritus of Abdera.

Although it must be admitted that a cloud of darkness hung over the science of astronomy at this early period, and the opinions and speculations of these philosophers were enveloped in vagueness and uncertainty, still the most splendid truths were mixed up with their errors, and theories were broached which the light of modern science, after a lapse of more than 2000 years, has proved, beyond the possibility of doubt, to be perfectly correct.

Thales believed that the moon borrowed her light from the sun, that her eclipses were caused by her immersion in the earth's shadow, that the earth was round, and he divided it into five zones; that the equinoctial line was cut obliquely by the ecliptic, and perpendicularly by the meridian. By the rules which he received in Egypt, he predicted an eclipse of the sun, though it is asserted that he only foretold the year in which it was to happen.

Anaximander taught that the planets were unconnected with this little globe which we inhabit, that they were peopled by living beings, that the fixed stars were the centres of other systems, perhaps more extensive and glorious than our own, that the sun was a body of fire, and that the earth moved round the centre of the system.

Anaxagoras predicted an eclipse of the sun, and taught that the moon was habitable, containing hills, valleys, and water, like the earth. He also promulgated the most splendid idea that a heathen philosopher could conceive—that there was but *one* God. For this heretical doctrine his countrymen condemned him to death; but his sentence was afterwards commuted to perpetual banishment, which, in those days, was tantamount to the last sentence of the law.

The celebrated philosopher, Pythagoras, taught these truths upon a more extended scale. Among his other doctrines, he held that the earth had a spherical form, that it revolved round its own axis in twenty-four hours, and round the sun in a year; that Venus was the morning and evening star. He imagined the universe to be composed of twelve different spheres—the sphere of the stars, of Saturn, of Jupiter, of Mars, of Mercury, of Venus, of the Sun, and of the Moon. These were succeeded by spheres of fire, air, earth, and water. He fancied that these solid spheres, in which the planets were fixed, emitted sounds during their revolutions. This idea, which arose from the ardour and brilliancy of his imagination, is called his doctrine of the "harmony or music of the spheres." The white colour of the milky-way he ascribed to the innumerable multitude of small stars of which it was composed—an opinion which has been exactly corroborated by the discoveries of the late Sir W. Herschel.

Philolaus taught these doctrines in public, which the prudence of his master made him disclose only to the initiated; and the consequence was, that the people rose in such hostility against him that he was obliged to fly the country.

The happy conjectures of these philosophers, being unsupported by argument or demonstration, became mixed up by their successors with such a mass of absurdity and error, that instead of being improved upon, they fell gradually into oblivion; and it was not till the establishment of the famous Alexandrian school, under the Ptolemies of Egypt, about a century and a half before the Christian era, that astronomy could be said to have assumed the form of a science.

## MINERALOGY.

### CHAPTER III.

We have now reached the second class of mineral bodies called metals. The number of these bodies is not accurately known, since we are frequently hearing of the alleged discovery of a new one, whilst on the other hand chemists deny the right of some already on the list to be there at all. We mentioned in the first of these papers that chemical research has shown that the bases of the pure earths are metals. Nevertheless since so little is known of their properties, and since, as metals, it has not been found that they form any part of the economy of the globe, and have not been made use of by man, we shall pass them by without description. All the metals are solid at the usual temperature of the atmosphere except mercury. Their colours are various as the common coins of the realm prove, with respect to the three kinds in circulation, but the majority are greyish white. They possess a peculiar lustre which has obtained the name of *metallic lustre.* They are perfectly opaque, at least none of them with the exception of gold have been reduced to such a degree of tenuity as will allow light to be transmitted. The light that passes through gold leaf is green. Only a few of the metals possess any smell. If iron, copper, lead, and tin, be rubbed they give out a peculiar odour, and if arsenic and antimony are heated they are found to have a similar property. Some metallic bodies are ductile and malleable; others will fall to pieces rather than extend themselves. The weight of metals differs very much, and so does their tenacity. Thus, whilst an iron wire of 0·840 of a line in diameter will support a weight of 549 lbs. avoirdupois, a wire of lead of the same diameter will break if more than 27 ℔ is suspended upon it. There is great difference also in the compactness and hardness of metals. Some are soft as wax, and others readily give way under the

finger nail; whilst a few can not be scratched by glass. It is well known that metals dilate with heat; the degree required to melt them is widely different. Thus the fusing point of mercury is 39° Fahrenheit, and manganese and malleable iron require the greatest heat of the forge before they lose their solidity. The conducting powers of metals for electricity vary considerably; the relative powers of copper and mercury, for example, being 100 and 3·45. Two only can be made permanently magnetic—iron and nickel.

The term *native metal*, signifies a metal which is found in the earth in a state of purity. This is not the case with many of them, and when it occurs at all, it is only in small quantities. Sulphur combines largely with metallic bodies, forming *sulphurets*; when the metals are combined with oxygen they are termed *oxides*; and the combinations with phosphorus are *phosphurets*.

*Platina* is a rare metal, discovered in the earlier half of the last century. It is found in grains in the Uralian mountains, St. Domingo, and in South America. In the Philosophical Transactions for 1829, Dr. Wollaston has given an account of the process of purifying platina. It has a greyish white colour, is very ductile and malleable; it can be made into wire not exceeding $\frac{1}{2000}$th of an inch in diameter, and it possesses a degree of tenacity almost equal to iron. It can only be melted by the oxyhydrogen blow-pipe, or by the application of voltaic electricity, but it may be welded at a high temperature, and by this means vessels can be made which are of great use to chemists. In the manufacture of sulphuric acid, the vessels made of platina are very useful. Its specific gravity varies a good deal, some specimens have been as low as 15, others as high as 23. It is used by opticians in reflecting mirrors, and it is also employed for astronomical and mathematical instruments. In Russia it is coined into pieces of money having a high value.

*Palladium* was discovered by Dr. Wollaston in 1803, in purifying some grains of platina. Specific gravity, 11 to 12. Colour, silver grey. It is malleable, hard, very difficult of fusion. Liquid nitrate of palladium is of a red colour, and the precipitate mixed with a salt of mercury forms a detonating powder.

*Iridium* was also discovered in 1803, and by the same process. It is brittle, has a specific gravity of 18 to 23, and has much of the appearance of platina. It is in doubt whether acids act upon the pure metal at all. The colours it assumes when combined with chemical agents are very numerous, and it derives its name from this circumstance, *Iris* being the Latin for a rainbow

*Osmium* is another rare metal, found combined with iridium amongst grains of platina. It is difficult to separate the two metals; the compound is called osmiuret of iridium. The specific gravity of the pure metal is 10, it is nearly white in colour, and it dissolves in nitric acid.

*Gold* is widely scattered over the globe, though found only in small quantities. South America furnishes the largest supply. It is found both native and combined with other minorals; the native variety is massive, crystallised, or capillary. Specific gravity, 17 to 19. When pure it is very soft and exceedingly malleable, so that it can be beaten into leaves one two-hundred-thousandth of an inch in thickness, and one grain can be made to cover 56 superficial square inches. It requires a high degree of heat to melt it. The fused metal is of a greenish colour, and crystallises as it cools. Its ductility is such, that 580 feet of wire can be drawn out of a single grain. The addition of a very small quantity of lead destroys its ductility. Gold wire, 0·787 of an inch in diameter, will bear about 150 lbs. The gold of our circulation is an alloy of one-twelfth of copper.

*Silver* occurs native and combined with other matters in many parts of the world. The primary form of the crystals of both gold and silver is a cube. Pure silver has a specific gravity of 10: it is soft; very malleable and ductile, but less so than gold. The leaves into which it can be beaten have seldom a greater tenuity than one ten-thousandth of an inch; and a wire thinner than a hair can be drawn from it. It is more tenacious than gold, for a wire of 0·787 of an inch in diameter will bear something like 187 lbs. It melts at a lower temperature than gold. Like that metal it does not tarnish by exposure to the air, but the slightest quantity of sulphur blackens it. This is the reason of silver spoons changing colour if used in eating eggs, for the yoke contains a little sulphur. Sulphur is found in a great number of combinations.

*Antimonial Silver* is fouud both crystallised and massive; specific gravity, 9. Hardness, 3·5. Colour, white. The antimony from 16 to 22 parts in the hundred. It is found in the Harz mountains, in the Tyrol, France, &c.

*Chloride of Silver*, or *Horn Silver*, occurs crystallised and massive; specific gravity, 4·75 to 5·55. Hardness 1. Colour green, blue, yellow, or grey. Mexico and Peru furnish the largest specimens of this ore; they are of a green colour. It is so easily fusible, that the flame of a candle will melt it.

*Sulphuret of Silver*, or *Silver Glance*, has a hardness of 2. Specific gravity, 7. Occurs crystallised and massive in Mexico, Saxony, and Bohemia. Colour, bluish grey; opaque. Sulphur forms about one-eighth of the mass; by heating the ore, the sulphur is expelled. Another compound is called the *Black Sulphuret*, from the colour. *Ruby Silver*, or *Braardite*, is a sulphuret of silver and antimony. *Miargyrite* is another union of the same substances. *Proustite* is a sulphuret of silver and arsenic. *Bismuthic Silver* is a sulphuret of silver, iron, copper, bismuth, and lead, of a bluish grey colour, occurring crystallised and massive.

*Selbite* is a carbonate of silver and antimony.

*Mercury* is not found in many places, but where it is met with it is usually in large quantities. Though fluid at ordinary temperatures, it becomes solid at 40° below zero, in which state it is malleable, and a knife cuts it without much difficulty. It crystallises as it solidifies, and contracts in bulk. Fluid mercury is inodorous and tasteless; it boils at 670° Fahr.; specific gravity, 13·5; it possesses the property of expanding with heat in a uniform degree from its freezing to its boiling point, and hence its use in ascertaining degrees of temperature. Native mercury is not of frequent occurrence; it has been found in Spain and Carniola; this is a very useful metal; the silvering matter of mirrors is made from it; it is used in the extraction of gold and silver from their ores, and the salts are extensively employed in medicine, under the names of calomel and corrosive sublimate.

*Bisulphuret of Mercury*, or *Cinnabar*, is the common state in which the metal is found in the earth; it occurs both massive and crystallised; hardness, 2; specific gravity, 3; colour, red of various shades. Artists use the bisulphuret under the name of vermillion. Cinnabar is obtained in large quantities at Almaden, in Spain, where government workmen are employed in excavating and purifying the ore; they produce upwards of two millions of pounds weight annually. These mines are very ancient; Pliny mentions them as producing in his day a great quantity of metal. An amalgam of mercury and silver is also frequently fouud, from which the mercury can be expelled by means of heat.

*Chloride of Mercury*, *Horn Mercury*, or *Baumerite*, is sometimes found in the mines. Subjected to the blow-pipe, the whole mass volatilises. Its constituents are chlorine, 15; mercury, 85.

*Copper* has a specific gravity of nearly 9; it melts at about 1196° Fahr.; it is very tenacious, 302 lbs. can be supported on a wire which is only $\frac{78}{1000}$ of an inch in diameter. Copper is a

very plentiful metal, and it is used in an immense number of ways. Native copper is found amorphous, crystallised, or dendritic. The sulphuret of copper (pyrites) is the commonest ore; Cornwall, Devonshire, Anglesey, and the English lake mountains yield great quantities of copper pyrites; it occurs crystallised, and in other forms—is of a bright yellow colour with a metallic lustre, and is very similar to iron pyrites, from which, however, it can be distinguished by its greater softness.

*Oxide of Copper*, or *Ruby Copper*, occurs in Cornwall in transparent octahedral crystals of a red colour, from which a metallic globule is obtained upon the application of heat.

*Carbonate of Copper*, or *Malachite*, occurs of a green or blue colour; it contains about 19 per cent. of carbonic acid. Fine specimens of Malachite are found in Russia; as it takes a good polish, it is manufactured into ornaments. The Queen has a splendid vase of Malachite presented to her by the Czar. The artificial carbonate of copper is used by artists under the name of verditer.

*Sulphate of Copper* is a good deal used when artificially made, by colourmen and dyers, under the names of blue vitriol and blue copperas. It occurs in nature, massive, stalactitic and botryoidal.

*Phosphate of Copper*, generally occurring in translucent crystals of a dark green colour, is found in Cornwall and Hungary. Phosphoric acid exists in it to the extent of 30 per cent.

*Arseniate of Copper* is also found as a native salt in a variety of forms and colours.

*Iron*, the most useful of all metals, is also the most widely diffused; it is very ductile, but not very malleable, and it is the most tenacious of metals. Specific gravity, 7·7. It requires a very high degree of temperature to melt it—it is doubtful whether it occurs pure in the earth, but large masses of native metal are frequently found upon the surface or just under the mould, the origin of which is involved in great obscurity; we allude to the masses called metenic iron: they usually contain a little nickel—one enormous mass, weighing fifteen tons, was discovered in Peru, and another, of a cellular structure, 1600 lbs. in weight, containing crystals of something like olivine was found in Siberia.

*Sulphuret of Iron* is a most abundant ore; magnetic iron pyrites occurs massive and in hexagonal crystals; hardness, 3 to 4; specific gravity, 4·6; it has a bronze yellow colour, with a metallic lustre. The sulphur forms about 36 per cent., whilst common pyrites contains 52 per cent. of that mineral; common pyrites has a hardness of 6; it occurs crystallised and massive, and has a brass yellow colour; large crystals are found in Cornwall—this ore is widely disseminated; when the sulphur is to be expelled by the blow-pipe, a magnetic oxide of iron is the residium. The native oxide occurs massive, of a red colour, oxygen constituting about 26 per cent.; it is found mixed with other ores of iron, and is generally the colouring matter in red minerals. What is termed magnetic iron, from its obeying the magnet, approaches very nearly to an oxide—and oligistic or spicular iron, which is also slightly affected by the magnet, is not very different in composition—it is constituted of about 31 oxygen and 69 iron. There is an ore with a foliated structure that has received the name of *Iron Froth*, which is almost a pure peroxide; it has a greasy feeling, and stains anything it touches; it is found in Devonshire and Lancashire.

*Hydrate of Iron* occurs massive and crystallised. The kind called Red Hematite is found in large masses at Ulverston in Lancashire, bearing the appearance of having suddenly cooled when in a boiling state; it contains a small quantity of silica. Brown Hematite is found in Cornwall, in a crystallised form; the massive variety contains a small quantity of manganese, in addition to silica.

*Carbonate of Iron* is found massive and crystallised in Cornwall, the Harz mountains, and America. It bears the names of Brown spar, and Spathose iron; hardness, 3 to 4; specific gravity, 3·7; lustre, vitreous; colour, white, yellow, brown, and red; it contains about 38 per cent. of carbonic acid. Argillaceous iron ore is a carbonate mixed with much earthy matter; a good deal is found with the coal deposits.

*Sulphate of Iron* in its native state is of a light emerald green colour, which changes to a greenish yellow, after exposure to the air. It is found both massive and crystallised in the mines of iron and coal; it is supposed to be formed by the decomposition of pyrites. The artificial salt is largely employed in some manufactures under the name of green copperas.

*Phosphate of Iron* is of a blue or green colour, found in the neighbourhood of pyrites; it is translucent, and both massive and crystallised. Some mineralogists have named it Vivianite. Two analyses found it to contain from 31 to 47 per cent. of the acid.

*Chromate of Iron* (from which the chrome yellow of artists is prepared) is found in America and Cornwall. It is of a dark colour.

*Arseniate of Iron* is found, both opaque and transparent, in various shades of green, brown, and yellow. When crystallised it occurs in cubes. It has about 18 per cent. of arsenic acid, and a little carbonate of lime in its composition; when heated, it becomes electric. A few other salts of iron are found in mines, but they are of rare occurrence.

*Manganese* is not known to exist in the shape of native metal. Its affinity for oxygen is so great, that when obtained pure by artificial means it decomposes if exposed to the air. Its colour is greyish white, it is hard and brittle, with a specific gravity of 7. It has neither taste nor smell, but if breathed upon, a smell of hydrogen gas is felt. A high temperature only will reduce it to fusion. The glass manufacturer uses it to produce a violet colour, united to oxygen in certain proportions it makes an acid known to chemists as manganic acid, which has not however been obtained separate from a salt. Its ores are principally oxides, and there are several varieties known as Braunite, Haussmanite, Manganite, Pyrolusite, and Varvicite. The most abundant is *Pyrolusite*, which occurs both crystallised and massive, the primary form of the crystal being a right rhombic prism; specific gravity nearly 5; hardness 2; colour black or nearly so. It is met with in Devonshire, and Warwickshire, and in Brazil. The oxygen is found upon analysis to amount to 35 per cent. The hydrated oxide is called black wad. It is of a brown colour, and contains a little iron.

*Silicate of Manganese* occurs massive and crystallised, of a red, yellow, or black colour; specific gravity 3·5; it is hard enough to scratch glass. The primary form of the crystal is an oblique rhombic prism. Silica forms about 48 per cent., and there is a little lime and magnesia in its composition. It is found in Cornwall, Devonshire, Germany, and Sweden. Before the blow-pipe it melts into a pale red glass. The minerals named allagite, rhodonite, and photizite, are silicates of manganese. A silicate of manganese and iron has been named kirebelite.

*Carbonate of Manganese*, or *Kohlerite*, has been found in Warwickshire and in Bohemia. It occurs both massive and crystallised, of a grey, brown, or rose-red colour. The primary form of the crystal is a rhomboid, and is translucent, but the massive variety is opaque.

*Sulphuret of Manganese*, or *Manganese Blende*, is of a brown-black colour, occurring crystallised and massive; specific gravity 4; hardness 3·5 to 4. The blow-pipe does not make much impression upon it. Sulphur constitutes about 37 per cent. It has been found in Mexico and Transylvania.

*An Arseniuret of Manganese* has been discovered in Saxony, of a grey colour, with a specific gravity of 5·5; and an oxide of

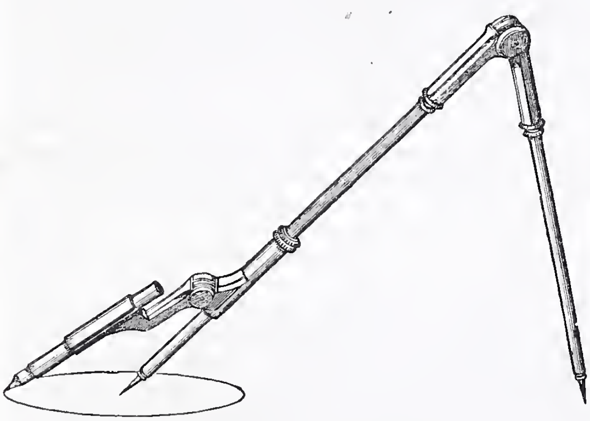
manganese with about 5 per cent. of an oxide of copper, occurring in Bohemia and South America, has been named *Cupreous Manganese.*

*Phosphates of Manganese* and iron are described by mineralogists under the names of *Ulmannite*, *Heteposite*, and *Huraulite*, but they are rarely met with.

The salts of manganese are used in the manufaeture of ehlorine and glass. Oxide of manganese removes a faulty yellow colour, which the last-mentioned substance is apt to take in making. In calieo-printing the sulphate is used to impart a brown tint.

## ELLIPTOGRAPHIC COMPASS.

Mr. Editor,—I beg to forward you a sketch of a simple instrument for drawing ovals, which I made several years ago, from a figure in an old work, and which only requires to be known, to come into general use, as from its simplicity and ready action, it will be found of great service to the perspective draughtsman. The eonstruction is so simple, as not to require a detailed description. To use it, set the point of the leg on which the pencil slides, in the centre, and the peneil to the half breadth of the ellipse, then extend the steadying leg until the pencil, as in the position shown in the figure, cuts the



length; steady the instrument with one hand, and with the other turn the pencil round, allowing it to slide up or down its guide, so as to keep the point pressing lightly on the paper. It must be clear that the figure described by the revolution of the pencil is a perfect ellipse, as it is an oblique section of a cylinder. When the ellipse is very long, this instrument will not answer well, but for a large proportion of those which occur in perspective, it will be found very useful; in this I can speak from experience.

I have shown both legs adapted to receive the pencil, and those of different lengths, as it will be more convenient than the old form with one round leg, if the ellipse is wanted nearly circular

Yours, &c.,

G. H. S.

## ON THE PREVENTION OF OXIDATION OF METALS.

The complete prevention of oxidation in metals exposed to the moist atmosphere, or the action of water, is by no means an easy matter, a fact of which most praetical men are well aware. Having felt the inconvenience severely on several occasions, I have been led to adopt a simple method of coating metals by the agency of an acid, so as to secure them most efficiently from the deteriorating influence of oxidation. The article to be eoated is first dipped in a dilute acid, eomposed of two parts sulphuric acid, and one nitric acid, in nine parts water. After immersion in this solution, the artiele is to be washed in clean water, precaution being expressly taken to avoid rubbing the metal, or touching it with the fingers. It is then to be allowed to drain, and so soon as it *appears to be dry*, it is to be brushed over with copal or lac varnish; the varnish attaches itself firmly to the acidulated surface of the metal, and never peels off. The best species of varnish for this purpose is probably eopal, to which is added a little litharge.

I have subjected sheet-iron, thus treated, to the continued action of sea-water for several months, without its sustaining any injury. It is perhaps worth while for shipowners to consider whether a considerable economy would not result from the application of this method to the copper sheathing of ships.

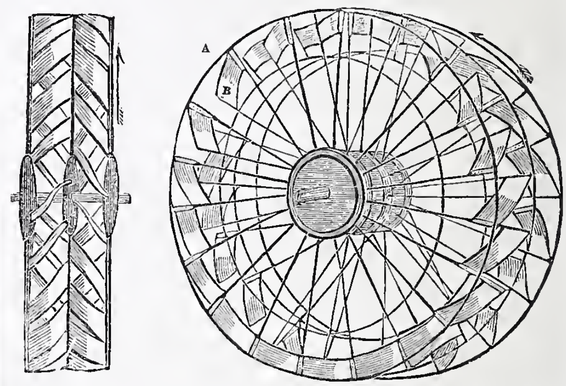
M. D. O.

## DOUBLE SCREW-PROPELLER "COBURG."

This invention promises a great improvement in the speed and comfort of steam vessels. Mr. Richard Chatterton, an Englishman by birth, resident at the port of Coburg, on Lake Ontario, Upper Canada, is the inventor and patentee.

A, Framework of the propeller, similar to that of a common wheel.

B, Floats or paddles of iron plate, or other suitable material, bent to the curve of the periphery, and fastened to the arms by screw bolts in the usual manner.



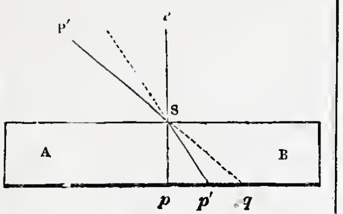

The figures in the engraving show the front and perspective views of the propeller, which is intended to be applied as an ordinary paddle-wheel to the side of a vessel; the distinction being, that whereas in the one case the floats or paddles enter and leave the water horizontally and at intervals, with violent successive concussion, and consequent disadvantage of downward pressure, unpleasant vibration and back lift, in the other they pass into and emerge from the sphere of resistance quietly and eontinuously, as a screw, without disturbing in front or lifting the water behind; at the same time being perfectly balanced at all points, as shown by the shading. Half of each float being precisely opposite a eorresponding half on the other side, and forming together, as it were, a succession of wedges in their action upon the water, the pressure on the shaft is quite as square as in the common wheel; while the displacement being the same, with a larger surface of friction exposed to the surrounding water, and the shape of the float being spiral, the propelling effect below is proportionately increased; on the well-known principle, that a body wedge-shaped offers greater resistance in its transit through water, with the point of the wedge foremost, than it would do if reversed, because it is more easily drawn from than driven against the frietion on its sides. Again, the water thrown abaft the wheel, on emerging, falls under the run of the vessel, helping to fill up the vacuum and urge her forward. The propeller has also the advantage of working much easier for the engine in a heavy sea, particularly a following sea, than the long square float; while in tide-ways, or ascending rapid currents, the continuity of its action must prove equally beneficial. Besides, it requires on wheels of large size a fewer number of arms than the common wheel: for instance, on one of 32 feet diameter and 10 feet breast, represented in the model, the difference is in the ratio of 19 to 30, or more. Such are the leading points of improvement claimed by the inventor and patentee, who estimates the gain of speed to be expected, as shown by experiment, to be at least a mile an hour compared with the old wheel, and with a total absence of vibration. Its powers can easily be tested, as the framework is exactly similar to that of the common paddle-wheel.

# NATURAL PHILOSOPHY AND CHEMISTRY.

## CHAPTER VIII.

### REFRACTION OF LIGHT.

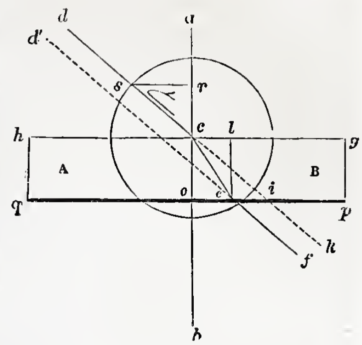
When a ray of light falls upon the surface of any uncrystallized transparent substance, as water, one part is *reflected;* another is *dispersed* in all directions, and serves to render the surface visible ; and the remainder penetrates the medium and pursues its course within it in a straight line, provided there is no change of density. If it fall upon the surface perpendicularly, nothing remarkable is perceived ; but should it reach the surface of the new medium—the transparent substance—by an oblique path, the ray is deflected from its antecedent course,—it is bent at the surface, and pursues a new course through the medium. Thus if A B represent a vertical section of a vessel of water ; a ray of light falling perpendicularly upon it, in the line P S, passes in a direct course to $p$ ; there is no deviation observed ; but when the ray is made to fall obliquely in the line P′ S, it suffers a bend at S, and proceeds to $p'$ instead of advancing along the dotted line to $q$. The converse of this is likewise true. Were the ray of light to emanate from $p'$ and emerge at S, it would not advance to Q, but take the direction S P′.




This deviation of the ray from the right line of its path, is called *refraction,* (from a Latin word which signifies *to break.*) As it takes place invariably when light passes obliquely from one medium to another, it may seem at first a matter of inconvenience, and there is no doubt that it often prevents our seeing objects in their true directions. A shilling for instance, placed at $p'$, appears to an eye at P′ to be at $q$. It is also in consequence of this same property that a stick partly immersed in water seems bent, and that a body of clear water always appears much shallower than it really is. The heavenly bodies, too, never appear to us in their true positions, except when they chance to be immediately over our heads ; the sun, for instance, is seen on the horizon in the morning before he is risen, and in the evening some instants after he is actually set. It is owing to the same cause that the discs of the sun and moon appear flattened in the direction of their height, when near the horizon. All the stars would exhibit the same appearance, could we measure their apparent diameters with the same facility and exactness.

These facts might be urged as imperfections in the code of Nature's laws ; but to counterbalance the apparent imperfection we have only to pursue this law in its consequences, and we find it merging into one of the most beautiful provisions for our convenience which come within the scope of physical inquiry, where all is admirable. Without refraction, light would, indeed, be to man—to animals generally, of little utility. There could be no such thing as a telescope, microscope, or lens of any sort ; and the human eye, one of the nicest optical instruments which can be conceived, would roll uselessly in its socket. This is a subject, however, to which we must hereafter return.

By comparing the direction of the refracted ray in the cases cited, in relation to the vertical line P $p$, it appears that the ray approaches the perpendicular on entering from air into water, and recedes from it in passing out of water into air. This leads to the conclusion, and it holds true generally, that light, passing from a rarer to a denser medium, is transmitted by a course which is more nearly perpendicular to the surface of the transparent body than the antecedent path ; and in passing from a denser to a rarer medium, the refraction is *from* the perpendicular. When the obliquity of the incident ray changes, the degree of refraction is likewise altered ; it is greater or less according as the obliquity is greater or less. There is, however, a beautiful and simple relation subsisting between them, by which we are able to predict the amount of refraction when the incident line is known. To explain this, we shall suppose that $a\ b$ is a right line perpendicular to the surface $h\ g$, of a piece of plate-glass A B ; if the ray fall obliquely, as from $d$ to $c$, it will emerge at the under surface $p\ q$ at $e$, being bent downward from its right path $c\ i$, into the line $c\ e$, nearer to the perpendicular $c\ o$, by a determinate quantity. To find the amount of this deviation, we have only to find the relation of the lines $s\ r$ and $o\ e$, which measure the angular distance of the ray from the perpendicular $a\ b$ before incidence and after refraction. But these lines are readily found thus :—Strike a circle from $c$ as a centre, and with $c\ e$ as a radius, in the plane of the ray $d\ c\ e$ ; then the line $s\ r$, drawn from the point at which the circle cuts the ray, perpendicular to $a\ b$, measures the angle of incidence $a\ c\ d$, and is called the *sine* of that angle ; and $e\ o$, drawn likewise perpendicular to $a\ b$ from a corresponding point of the refracted ray, measures the angle of refraction $o\ c\ e$, and is in like manner called the *sine* of that angle. These lines are not equal in length, but are to each other in a constant ratio for the samo transparent medium. In the case supposed, where A B is plate glass, the line $s\ r$ is a half longer than $o\ e$, or an equal line $c\ l$, and this is expressed by saying that the *index of refraction* is $1\frac{1}{2}$, and is found by dividing $s\ r$ by $o\ e$ or $c\ l$. This, moreover, holds true for all degrees of obliquity of the incident ray, so that the angle of incidence being given, the direction of the refracted ray may be foretold. From this illustration, it is also very clear, that the incident and refracted rays must always be in the same plane, but on different sides of the perpendicular $a\ b$.




The index of refraction is, however, by no means uniform. As already observed, it bears in general some relation to the density ; it increases for instance through the list—air, water, sulphuric acid, alum, glass, and so on ; but it is further observed, that inflammable substances are generally possessed of higher refractive powers than those which do not belong to that class. It was the discovery of this fact which led Newton to the celebrated statement, that the diamond, whose refractive index is about $2\frac{1}{2}$, consists of a combustible substance ; and that water, whose index is $1\frac{1}{3}$, contains an inflammable constituent. Modern chemistry has verified the correctness of Newton's prophecy ; but still we are as yet unable to connect the refractive power of a body with its chemical constitution in any positive manner. Thus we find hydrogen, sulphur, phosphorus, wax, turpentine, camphor and oils, distinguished by refractive powers much greater in respect to their densities than most other substances, and strictly bearing out the Newtonian prediction ; but on the other hand, we find chromate of lead possessing the power in a very extraordinary degree, although it cannot with propriety be brought under the head of combustible.

It might at first be supposed that as all rays of light which fall obliquely upon a plate of plane glass are invariably refracted, objects seen through it ought to appear distorted. This does not however follow as a necessary consequence ; for the ray $d\ c\ e$, on emerging at $e$, is refracted to the same amount as at its entrance, and passes on in the direction $e\ f$, appearing to an observer at $f$ to have come along the line $d'\ e\ f$ parallel to its real course $d\ c\ e\ f$. Hence in looking through a window, although an object is not in reality seen in its true place, yet as all the rays which it transmits are similarly affected, the object is not distorted provided the opposite sides of the glass are perfectly parallel.

Many experiments have been made to determine the refractive indices of diaphanous bodies ; and from these the absolute refractive powers in relation to the density are calculated. We subjoin a table of the principal of these, chiefly with a view to subsequent reference. It may be observed that the refractive powers are calculated on the supposition of the ultimate particles of bodies being all equally heavy, by dividing the excess of the square of the index of refraction above unity by the specific gravity of the substance. The results are the following :—

| Name. | Index of Refraction. | Absolute Refractive Power. |
|---|---|---|
| Vacuum, | 1·000000 | 0· |
| Hydrogen, | 1·000138 | 3·0953 |
| Oxygen, | 1·000272 | 0·3799 |
| Common air, | 1·000294 | 0·4528 |
| Nitrogen, | 1·000300 | 0·4734 |
| Ammonia, | 1·000385 | 0·4734 |
| Carbonic acid, | 1·000449 | 0·4537 |
| Chlorine, | 1·000772 | 0·4813 |
| Tabasheer, | 1·111 | ? |
| Fluids in topaz, | 1·294–1·31 | ? |
| Ice, | 1·309 | ? |
| Water, | 1·336 | 0·7845 |
| Ether, | 1·358 | 2·56 |
| Alcohol, | 1·372 | 1·0121 |
| Hydrochloric acid, | 1·410 | 0·5514 |
| Nitric acid, | 1·410 | 0·624 |
| Sulphuric acid, | 1·434 | 0·6124 |
| Fluor-spar, | 1·434 | 0·3414 |
| Alum, | 1·457 | 0·6570 |
| Oil of olives, | 1·470 | 1·2607 |
| Oil of turpentine, | 1·475 | 1·351 |
| Castor oil, | 1·490 | 1·148 |
| Oil of cloves, | 1·535 | 1·309 |
| Crown glass, | 1·525–1·534 | 0·526 |
| Plate glass, | 1·514–1·542 | ? |
| Amber, | 1·547 | 1·3654 |
| Quartz, | 1·548 | 0·5415 |
| Flint glass, | 1·585–1·60 | 0·7986 |
| Oil of cassia, | 1·641 | 1·7634 |
| Sulphuret of carbon, | 1·768 | 1·4200 |
| Sapphire, | 1·794 | 0·5556 |
| Garnet, | 1·815 | 0·5423 |
| Zircon, | 1·961 | 0·6054 |
| Sulphur, | 2·148 | 2·2000 |
| Phosphorus, | 2·224 | 2·8857 |
| Diamond, | 2·439 | 1·4566 |

—*Dr Golding Bird.*

In this table the ray is supposed to enter the medium from a vacuum; but it is often of importance to be able to determine the direction of a ray passing from one refracting medium to another. In this case, we take the ratio of the first index to the second, and the quotient is the new index of refraction. Thus supposing that we want to find the index of refraction of a ray passing from plate glass into water; the index of the former is $1\frac{1}{2} = \frac{3}{2}$, and of the latter $1\frac{1}{3} = \frac{4}{3}$; then $\frac{4}{3} \div \frac{3}{2} = \frac{8}{9}$, is the required index. For greater accuracy, the decimal numbers given in the table may be taken.

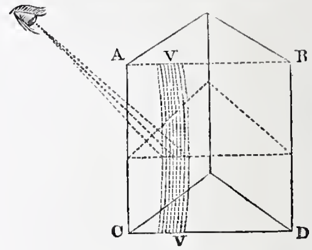
We have said that when a ray falls perpendicularly upon the surface of a diaphanous body, it is not refracted, but continues its course in a straight line; in all other directions it suffers refraction, and can always pass from a vacuum into a denser medium. But there are certain cases in which the reverse of this does not hold. To understand this, it is necessary to refer to our preceding figure. Here we observe that the ray is incident from *d*, and the *sine s r* is greater than the *sine o e*; but were the ray incident at so great an obliquity, that *d c* would nearly coincide with *h c*, the surface of the glass, the *sine s r* would nearly coincide with the radius of the circle, and the luminous ray would only graze the surface of the medium *g h p q*, but still a considerable portion of the light would really enter and be refracted, since the sine of refraction *o e*, in a dense medium, is always *less* than the sine of incidence *s r*. The converse of this is remarkable, though equally plain. If *f c* be a luminous ray passing through the dense medium into the rare one, the sine of refraction, as already noticed, will exceed that of incidence; and when *f c* is incident in a direction nearly coinciding with *g c*—that is, when *o e* nearly coincides with the radius of the circle—the ray does not pass out of the dense medium, but is *reflected* from the surface *g h* back again into the medium *g h p q*, according to the ordinary law of reflection already explained. The remarkable circumstance connected with this sudden conversion of refraction into reflection is its affording the only instance of *total* reflection which has yet been discovered; the ray in this case—supposing it incident in a dense medium on the surface of a rarer one, at a sufficient obliquity—is wholly reflected without any diminution of intensity.

The angle at and within which this *internal reflection* takes place, is called the *limiting angle* between refraction and reflection, and is of course different for different substances.

| | | | |
|---|---|---|---|
| In Water it is | 48° | 27′ | 40″ |
| " Crown glass, | 40 | 39 | — |
| " Flint glass, | 38 | 41 | — |
| " Diamond, | 23 | 42 | — |
| " Chromate of lead, | 19 | 28 | 20 |

The angle may be found for any diaphanous substance by dividing 1 by the index of refraction of the substances, and looking for the quotient in a table of natural sines,—the angle corresponding to it is the limiting angle.

The brilliancy of the light reflected at and within the limiting angle is readily observed by nearly filling a glass with water, and holding it up so that the surface of the fluid may be seen from beneath; it will appear like a sheet of burnished silver from the reflection of the incident light, and no object held above it will be visible so long as the eye is within the prescribed angle. A still more beautiful experiment is described by Newton. Hold an equi-angular prism in the position shown in the figure, before an open window, in such a manner that a line drawn from the eye may describe an angle of about forty degrees with the base of the prism. The base A B C D, will appear to be bisected by a curved iris, V V, of a bluish violet colour; the space between V V A C appearing of a sombre hue, in which reflection is extremely imperfect; but beyond V V including the space V B V D, the whole appears shining with metallic splendour,—the clouds and surrounding objects being depicted upon it in great brilliancy. The iris V V thus divides the space between partial and total reflection.*




When rays of light traverse a medium of variable density, their direction is modified at every instant, and their path becomes a curve. Thus, supposing that we pour water into a vessel, and over it a quantity of alcohol; a ray passing through the *mixing* liquids will follow a course compounded of the refraction due to the liquids taken separately. It is in the same way that the light of the heavenly bodies traverses our atmosphere in a curve which has its concavity towards the horizon, thus answering to the continually increasing density which it encounters in its path. It may also be observed, that in certain states of the air—depending chiefly upon its humidity and warmth—the refractive power is very sensibly affected. In one state, a distant hill may appear low, and scarcely showing itself above the intermediate heights; while in another state, the same object may be seen towering high over all that intervenes. The subject indeed of atmospheric refraction is one of considerable interest, and may be a little more attentively examined. All those phenomena, known by the names of *Enchanted Island, Cape-fly-away*, the *Flying Dutchman*, &c., are explained by it, and are all comprehended in the explanation of *mirage*. This optical illusion has excited much attention, and in some of its varieties has not unfrequently afforded rich food for superstition to live on in days of ignorance.

Perhaps the best known variety of mirage is that common in Egypt, and which so cruelly tantalized the parched throats of the French soldiers during the campaign of Napoleon in that country. Monge, one of the savans who accompanied the army, describes it thus:—The soil of Lower Egypt is an immense plain; it is perfectly horizontal, excepting that it is interrupted by a few eminences on which the villages are built to secure them from the inundations of the Nile. In general the atmosphere is calm and clear, and in the mornings and evenings the aspect of the country presents nothing remarkable—all the objects appear at their proper distances, and in the natural positions; but as the day advances, and the heat increases in intensity, the prospect seems bounded by a general inundation, in the

* See Dr. Golding Bird's Elements of Natural Philosophy, pp. 309 and 310: and Newton's Optics, lib. iii. Exp. 16.

midst of which the villages appear like islands, accompanied each by an inverted image as if reflected from the surface of a sheet of water. But as the observer advances towards the object, he discovers only hot and burning sand; the deceptive inundation continually recedes, and the reflected images vanish to be succeeded by others at greater distance. This phenomenon was equally novel and distressing to the French soldiers; when they saw at a distance on the burning plains the reflection of the sky, the inverted images of houses, of palm-trees, and all the objects on the horizon, they could not doubt but that they were formed by reflection at the surface of some lake. Fatigued by forced marches under an intense sun, and in an atmosphere full of burning sand, they ran towards the imagined water; but it fled before them.

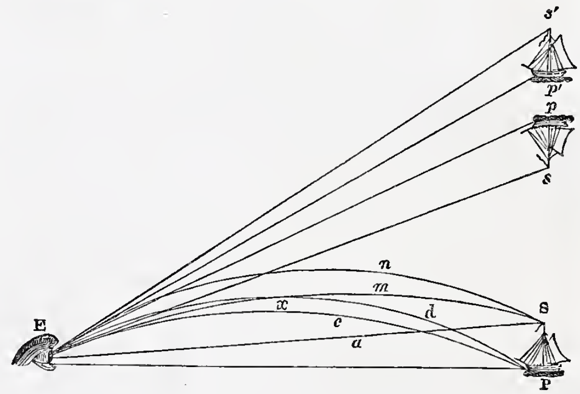
This kind of mirage is not peculiar to Egypt; it is known in Persia under the name of *Sir-āb*, (miraculous water); it has been observed in the western deserts of India, on the sandy beach of Dunkirk, along the coast of the department of Calvadoes, at the Cape of Good Hope, and at the Shallout Pass in India. It is not, however, wonderful that it should be observed in other countries besides Egypt; it must always take place when the necessary circumstances concur to produce it without reference to geographical position. These circumstances are not of difficult explanation.


Suppose that $c\ d$ represents the level of the soil which is very much heated by the sun; then the stratum of air immediately in contact with it will be rarified, and will increase in density for a certain distance upward; at some point the density will be constant, and will then begin to *decrease* upward according to the known laws of the constitution of the atmosphere. Under these circumstances, let us consider how the rays of light from an elevated object A will reach the eye of an observer at E. It is evident, first, that the eye will perceive the object directly by the rays in the direction A E; these rays will not come absolutely straight; they will be slightly curved, which will give a slight elevation to the object A, as if the whole level were raised to $a\ b$; but this deviation may be left out of consideration as regards the direction of the ray A E. The object A, however, transmits rays towards the ground, and these are refracted from their direct course on entering the less dense inferior strata of air, and, taking at first a direction inclined to the horizon, are afterward bent up so as to reach the spectator's eye at E. The spectator, therefore, sees the object by a direct set of rays A E, and by a set of refracted rays denoted by the curves A E; but as the eye takes no cognizance of curvature, it deems the rays to proceed in the right lines B E, which should be represented as tangents to their corresponding curves A E. And, moreover, as the rays from that part of the heavens, upon the back ground of the object, are refracted in the same manner, the sky is reversed as well as the object, and presents the appearance of a sheet of water.

This is the sum of the explanation given by Monge, on the occasion of the phenomenon being observed. That it is correct, may be proved by a very simple experiment. Suppose we make a bar of iron—a thick poker—red-hot, and look along its surface at some object; there will be seen an inverted image as well as the object itself; thus showing, that the strata of air over the heated surface of the iron are affected in the same manner as the air eumbent upon the hot sandy plains of Egypt. A still better example is afforded, by looking over the boiler of a locomotive on a cold still day. Something analogous is also observed in the tremulous appearance of the objects of a landscape, in a very clear warm day in our own latitude, although the phenomenon perhaps never attains so decisive a character, as to warrant our classing it with the mirage of Egypt.

There is another kind of mirage which is equally remarkable, and which takes place under exactly opposite circumstances from those explained. Perhaps the most celebrated example of this is, the case described by Captain Scoresby, in which he recognised his father's ship, the Fame, by its inverted image suspended in the atmosphere, at a time when it was 30 miles distant, and consequently beneath the horizon. The famous Fata Morgana, visible at Reggio, and which for many centuries astonished the ignorant and perplexed philosophers, is another instance of the same sort of phenomenon. When the sun's rays are thrown upon the bay at an angle of 45°—the surface of the water being perfectly still, and the tide at its height—a spectator placed on an eminence in the city, with his back to the sun, and his face to the sea, the mountains of Messina rising like a wall behind it, and forming the back-ground of the picture—on a sudden there appears in the water as in a catoptric theatre, various multiplied objects—numberless series of pilasters, arches, castles, regular columns, lofty towers, superb palaces with balconies and windows, extended alleys of trees, beautiful plains with all their herbage, herds and flocks, armies of men on foot and on horseback, and innumerable other things all in their natural colours and proper actions, passing rapidly in succession along the surface of the sea. These same objects are, in particular states of the atmosphere—when it is highly impregnated with vapour—seen in the air, though not so distinctly and well defined; and when the air is slightly hazy and opaque, they appear at the surface of the sea, but all vividly coloured or fringed with red, blue, green, and in short all the prismatic tints. All these images constituting this gorgeous phenomenon are derived from objects on shore, by atmospherical refraction. Similar phenomena have been observed on our own coasts, and may occur in all latitudes, though some localities may be more favourable than others for the full development of the illusion. The whole may be included in one explanation.

If the lower stratum of air be denser than the strata above it, the rays which diverge from it, in such directions as to pass obliquely into the strata of changing density, will proceed in curves *concave*, towards the earth; and as before explained, when such rays meet the eye of a spectator, he conceives the object to be situated in the direction of a tangent, E $s'$ to the refracted ray, E $n$ S, and the object therefore appears as if suspended in the air. In the case here assumed, we have supposed two suspended images, as frequently happens; and further, that the one is direct and the other inverted. The conditions necessary to this illusion are, that the rays diverging from each point of the object shall encounter strata of such densities, that the eye may receive two sets by different paths. The rays S $n$, and P $c$, reaching the eye, give by their tangents, the image $s'p'$; but the rays S $m$, and P $d$, meet with such variation of density as to make them cross each other at $x$; whereby P $d$ is uppermost by the time they reach the spectator's eye, and their tangents consequently give the inverted image $p s$. The state of the air may be such as to give only one such image, or many; and when the object is above or below the horizon. The elevation of coasts, mountains, and in fact all the phenomena which, when seen over a surface of the sea, we call *looming*, are instances of refraction comprehended in the explanation, and may constantly occur.




When vertical masses of air, instead of horizontal strata, are affected so as to produce different densities, we have what is termed lateral mirage. It is by this lateral mirage that the French coast has been seen to approach almost into contact with our own; and that Dover Castle has been brought over and placed on the Ramsgate side of the hill. This kind of mirage is by no means of rare occurrence.

# MECHANICS.

## PRELIMINARY REMARKS.

Mechanics, regarded as a science, comprehends the sum of our knowledge relative to the sensible motions of bodies, either actually existing or suppressed by the opposition of forces tending to produce motion. The science is thus resolvable into a code of discovered laws, applying to the causes which occasion and modify the direction and velocities of motion, and is therefore distinct from those branches of science in which, although presenting phenomena of motion in sensible portions of matter, we do not consider the circumstances and laws of these motions, but only the effects produced. When motion itself is considered, the reasoning belongs to mechanics; and it is probable, that as our knowledge of the laws which govern the phenomena that are evolved under the hand of the experimental philosopher, becomes more extended, a wider meaning will be given to the science of motion.

The definition which we have given of mechanics is not coeval with the name. The science, like most other sciences, has gradually expanded to its present extent. It was originally the *science of machines*—these being the first subjects of its speculation—and as every material combination, employed for producing or preventing motion, may be regarded as a machine, and may be resolved into the same elementary principles as those employed in machines—the *mechanical powers*—the name "Mechanics" became to be applied to motion, and the tendency to motion of any bodies whatever. Mechanics still continues to be defined by some, the *science of force*, and there does not appear to be any valid objection to the definition. Force is the cause of motion, and its laws are identical with the laws of motion, and consequently the science of force coincides, in all its parts, with the science of motion, which is mechanics.

The *foundation* of all philosophy is the principle that nature acts by general laws; and the *object* of all science is the investigation of these laws. This principle is perhaps more fully recognised by mechanics, than by any other department of general science. The subjects which it embraces are extensive and complex, when viewed in their operations, and in their results; but by limiting its energies to motion and its causes, it speedily succeeds in classing the phenomena, and resolving them into a very few elementary conditions. Even experiment is not in all cases necessary; "for since we suppose all the phenomena of motion to take place in consequence of the laws which connect them with their causes, it follows that this connexion must supply the reasons why they take place in one way rather than another; and that therefore, when there is no reason why an event should happen one way rather than another, it will not happen at all. In other words, since nature acts by general laws, no law which is not general, can be a law of nature. Again, those laws of motion, which cannot be detected by so general a consideration of the constitution of the universe, must be obtained by closer observation, and by experiments expressly for the purpose. The facts, however, of which we treat, are so simple, and the principles so few, that a very small number of very obvious experiments affords a firm foundation for the whole superstructure of mechanics."—*Whewell's Mechanics.*

The subjects of consideration comprehended in mechanics are, *body*, with its power of resistance; *motion*, with its essential conditions of space and time; and *force*, as the cause producing and modifying motion. These are the few ideas with which we are concerned, and whose relations we are called upon to examine and express. The countless varieties of form under which they present themselves do not come farther within the scope of our investigation, than as particular examples of the general laws with which they conform. *Body* or *matter*, and *space*, require from us no other explanation than is contained in the general conception of them, which the terms suggest when we say that *body* exists and moves in *space*, except it be that we suppose space, when not otherwise expressed, a vacuum in which bodies move in all directions with perfect freedom. The conception of *motion* which we have is equally simple and suitable: it is suggested to us on all sides, and at all times, by the changes in situation of things around us. The idea of *force*, again, is thoroughly impressed upon the mind by the perpetual succession of rest and motion in material things, and by our own consciousness of the exertions by which we begin and arrest motions.

We may in future require more precise definitions, but it will be advantageous to supply them as they are wanted: they will then be immediately available without retrograde reference. It may also be observed, that although we intend this course to be strictly elementary, and suited to those who have made but limited progress in their mathematical reading, we shall endeavour to treat the subject as systematically as the nature of our object will admit. In order to accomplish this, we shall divide our subject into two great divisions; the first comprehending the consideration of forces acting upon a body, to keep it at rest; and the second, the discussion of the laws of motion as distinguished from those of rest; and which requires the consideration of principles which the examination of those of our first division will prepare us to apprehend. These divisions are known by the names of *statics* and *dynamics*—the former derived from a Greek word (στωτὸς), implying *rest* (standing still); and the latter from another Greek word (δύναμις), signifying *power*, and hence applied to force, coupled with motion.

## PART I. STATICS.

### CHAPTER I.

1. Definition of Force.—2. Equilibrium of Forces. Pressures.—3. The Equality of Forces.—4. The Direction of Force.—5, 6. Magnitude of Force. Measured by Weight.—7, 8. Forces may be represented by Lines, in Magnitude and Direction.—9. Two Forces cause Equilibrium only when they act in contrary Directions.—10. Point of Application of Force. Effect the same, wherever applied in the Line of Direction.

1. Force, we have said, is that which causes motion. When we pull the string of a bow, we are conscious of exertion—the bow resists the pull by a force just equal to that which we apply to the string; and hence, after it has quitted the fingers, it presses upon and impels the arrow—it expends the force upon it which was applied by the hand in pulling the string. With such an instrument and a similar application of force, we can always produce motion. When we push bodies, we likewise invariably cause them to move by the application of a greater force than the opposing force which the body exerts. So long as circumstances remain the same, we always expect the same effects from the same amount of physical exertion, and we are never disappointed. But here a consideration intervenes. The power of the human muscles and the elasticity of the bow are causes of motion, and come therefore under the definition—they are force. But if different forces—all sufficiently intense to cause sensible motion—act upon the same object at the same instant, will motion invariably ensue? We know from numerous familiar instances, that this is not necessarily the case. In the case of the bow, we know that the instrument may be bent and kept in a state of tension, but no motion of the arrow takes place till the string is allowed to quit the fingers: it is kept at rest by the opposing forces, the right and left hands. A weight placed in the scale-pan of a weigh-beam causes it to descend; but if a counterpoise be placed in the opposite scale-pan, motion is destroyed. A hand too may sustain a weight, and prevent its descending to the ground by the force of its own gravity; and a machine may in like manner hold motionless a load which it has elevated. These are cases wherein force is employed, not in producing, but in preventing motion. It is therefore not essential to the nature of force that it should actually produce motion; but only that it should cause motion when not counteracted by other force. By these considerations we are led to enlarge our definition, and to regard *force* as that which *causes* or *tends to cause* motion, or which *destroys* or *tends to destroy* it. To this we may add, that the subject of motion, or a tendency to motion, is *matter*.

2. We may conversely lay it down as a fixed principle, that when the tendency of a force to communicate motion does not take effect, there exists some other force of an opposite tendency, and which is the cause of the quiescence. The state of a body in which, being acted upon by certain forces, it remains at rest, and which may be called its state of *forced rest*, is denominated its

state of *equilibrium*, and the forces which induce that state, are said to be *forces in equilibrium*, and to distinguish them from unbalanced forces, are termed *pressures*.

The idea of forces which act by pressure is among the most familiar which we derive from our every-day observation and experience. "Everything that we take up, support, or lay down—everything which we thrust, push, pull, or draw—every case in which we see this done—everything which is moved or supported by a weight, or by the elasticity of a fluid—that is, with very few exceptions, every case of continued action—gives us this idea." The idea is indeed suggested to us by every body which appears to us to be at rest—rest being the state which we denominate equilibrium, and which we conceive to be brought about by opposition of forces which destroy or counterbalance one another, and these forces are *pressures*.

The conception then which we are required to have is, that pressures are forces whose tendency to produce motion does not take effect; they produce equilibrium, and the code of laws which govern the various relations of forces of pressure constitutes *statics*.

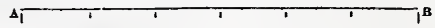
3. In considering equilibrium, the things to be noticed are the *direction*, *magnitude*, and *point of application* of the forces. It is not necessary that we should define the kind of each force; for all forces being known to us only by their effects, we conclude without hesitation, that *any* two are equal, when, if applied in the same manner, and for the same time, they produce the *same* effects. For instance, if a certain weight hanging freely over a pulley would just be sufficient to prevent a carriage from running down an inclined plane, that weight is exactly equal to the force which a horse must exert, in order to keep the same carriage at rest in the same situation. Thus, animal force may be compared with weight or the force of gravity. In the same way we may compare the elasticity of a spring, with muscular force, magnetic attraction, gravity, or weight, and in short any variety of force which we can imagine to be placed in opposition to it.

4. The effect of a force depends upon its *direction* and *magnitude* conjointly. By the direction, we understand the straight line in which the force tends to cause, prevent, or destroy motion. For example, when a bullet is dropped from the top of a perpendicular building it falls in a straight line to the bottom. The *direction* therefore of the force which makes the bullet fall—its weight—is sensibly a vertical line; and if this line be drawn, the force is said to act *in* it. It is not however necessary that the bullet be actually dropped to find out the line of direction of the force of gravity. If it be suspended by a string, the string will be in the direction of the force; for there is no general law determining it to move on one side rather than another. This principle, indeed, gives us one of the easiest practical methods of finding perpendicular and horizontal lines. The instrument alluded to is the plumb-level, which, in some one or other of its forms, is known to everybody, and understood by everybody as an imbodiment of the idea, that the direction of the force of gravity in the plummet is in the line occupied by the string which suspends it. The direction of the force which prevents the vertical motion of the plumb is moreover in the same line, but acts in an opposite direction: the action of gravity is counteracted by the tension of the string, and this again is counteracted by the resistance of the point of support—and these forces are equal and opposite.

5. These considerations bring us to the *magnitude* of force. This is measured by the effect which it would produce under given circumstances, compared with the effect produced under the same circumstances, by some other force taken as a standard. It must be borne in mind, however, that the effect which we are called upon to consider, in statics, is the power of producing equilibrium; and hence, two forces which exactly counteract each other are reckoned equal. They are moreover measured by what they will sustain in equilibrium. The standard which naturally suggests itself to the mind is *weight*,—the weights of different bodies—that is, their tendencies to the earth are different, and require different forces to counteract them. They may besides be named in precise quantities, and hence afford a scale which may be applied to the measurement of all forces whatever. We may take our unit what we please: for instance, a common one-pound weight of iron, which is nearly $3\frac{1}{2}$ cubic inches. This being assumed as a unit, any other weight that produces the same statical effect is likewise one pound. Thus, $2\frac{1}{2}$ cubic inches of lead, suspended from the end of a spring, will bend it as far as $3\frac{1}{2}$ cubic inches of iron; the masses are therefore equal, and either may be taken as the unit, *one pound*. In like manner, we may obtain any number of masses of any materials whatever, each equal to one pound; and again, we may find a mass which shall produce the same mechanical effect as two, three, or more of our units, and such mass is said to be equal to so many pounds.

6. Any other statical force may be measured in the same way as weights; for any other statical force may be measured by the weight it would support; and wherever force is employed in producing equilibrium, the same effect might be produced by a weight. The force of the hand may, for instance, be employed in drawing a bow, and in balancing its elasticity; but the bow might be bent, and its elasticity balanced by the application of a weight to its string—this weight being moreover an exact measure of the muscular exertion expended in producing the effect by the interposition of the hand.

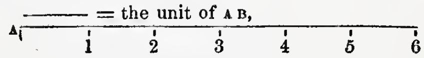
7. In investigations, relative to the values of forces, it is besides very often convenient to represent the forces by lines such that their lengths shall represent the magnitude of the forces. Thus, if we take a line, A B, composed of any number of equal parts,



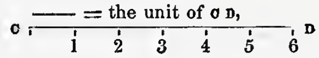

—— = the unit,

and each part equal to the unit assumed; then the whole line conveys to the mind an accurate idea of a force of as many units as there are such parts in it. It is further obvious, that upon this supposition, the *actual* length of the line is of no moment; for two lines, A B and C D, of different lengths, will represent the

—— = the unit of A B,

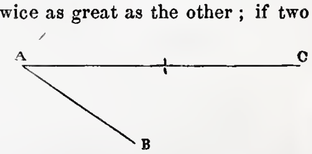



—— = the unit of C D,




same force, provided proportional values be given to the units of which they are respectively composed. Thus, taking the unit of A B as one pound, and the unit of C D as one pound, then the lines A B and C D respectively represent a force of six pounds.

8. This method has the further advantage, that the lines may always be made to indicate the direction of the forces as well as their magnitudes. Thus, suppose we have two forces acting upon a point in directions inclined to one another at a certain angle, and that one force is twice as great as the other; if two lines, A C and A B, be drawn at the given inclination, and of lengths corresponding to the magnitudes of the forces, these lines will afford a precise conception of the relations of the forces, both as regards their magnitudes and directions.

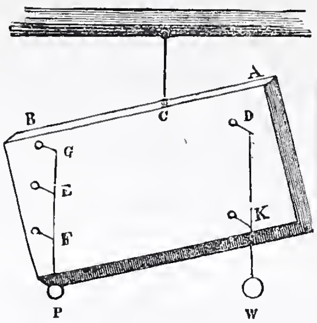



Diagrams of this kind are even made further expressive by the order in which the letters upon them are read. Thus, "a force A B," implies a force acting upon A proportional in magnitude to the line A B, and tending to cause motion *from* A *towards* B; whereas "a force B A," implies an equal force tending to cause motion *from* B *towards* A. The conception of our diagram is therefore complete, if, when the forces act *towards* A, they are supposed to be represented by B A and C A, and by A B and A C when they act *from* it. In representing forces in this manner, the conception is farther assisted by terminating the lines denoting them by arrow-heads, the arrow being pointed in the direction of the force; that is, in the direction in which it tends to produce motion.

9. It is found by experiment, that a body urged by *two forces* is in equilibrium only when these forces are equal and act in contrary directions; that is, in the same straight line. It is therefore clear that the two forces expressed by the diagram above cannot hold the point to which they are applied, at rest; for they are neither equal to one another, nor do they act in opposite directions in the same straight line. To induce equilibrium, a *third* force must necessarily be introduced; but the method of determining its magnitude and direction must be left for subsequent consideration.

10. By the *point of application* of a force is meant the point where the agent is supposed to be in contact with the body. Thus, when one body strikes another, the point of contact may

be supposed to be the point of application of the force; and, "if the force be exerted on the body by means of strings or rods, it may be supposed applied at the point of the body to which the string is attached, or against which the rod pushes. If a body be attracted, the force on each particle may be supposed applied at the particle." But it is found experimentally, that the effect of a force acting in a given direction on a solid mass—that is, a mass whose particles are firmly bound together by the force of cohesion—is the same at whatever point it is applied to it, provided only that the point lie in the direction of the force. Thus, suppose we have a piece of wood, A B, suspended freely by a string attached to its upper edge at C; then if two weights, W, and P, be hung upon two small pegs fixed into the wood at D and E, and the whole left to attain a state of rest, the two strings, D W, and E P, hanging perpendicularly along the surface of the wood, will point out the direction of the forces, W and P. If now the weights be shifted to other pegs in these lines, W to K, and P to F or G, the whole will still be found to balance itself, and the lines of direction of the forces will remain unaltered. This experiment, therefore, shows very clearly that the effect of a force is the same at whatever point in the direction of the force it is applied.

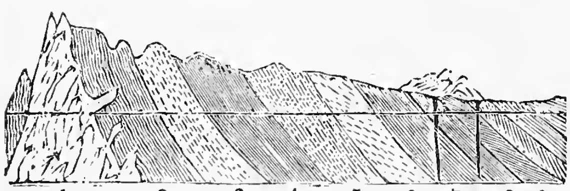



Our next business is to deduce the laws of equilibrium from these definitions, and such additional inferences from observation and experiment as it may be found necessary to introduce.

# GEOLOGY.

## CHAPTER IX.

### GRANITIC AND PRIMARY CRYSTALLINE ROCKS.




1. Granite. 2. Gneiss. 3. Mica schist. 4. Clay slate. 5. Silurian rocks. 6. Old red sandstone. 7. Mountain limestone. 8. Lower coal formation. 9. Upper coal formation.

*Granite.*—The consideration of granite is of high geological importance, and hence it has claimed no small share of the attention of many of our most eminent geologists. Occurring as it always does in the crystalline form, we have the most distinct proof of its having originally existed in a fluid state; and this proof is rendered still more decisive, when we examine the manner in which it is often found injected in the form of veins into superincumbent strata. Granite was long considered as representing the primordial condition of terrestrial matter, and as having formed the original external coating of the globe, which being acted on for ages by the atmospheric or aqueous agencies, gave origin to the stratified masses which are now generally found resting upon it; but the discovery by Hutton of granite penetrating strata of limestone and schist, in Glen Tilt in Perthshire, led to farther discoveries of the same kind, and to the important conclusion, that in granite itself we find no trace of the original condition of rocky masses; and to the still bolder hypothesis assumed by Mr Lyell, that granite itself is the particular state of combination into which stratified deposits may be converted by the agency of heat.

Did granite only affect the early non-fossiliferous strata, we might naturally conclude that its production belonged exclusively to the first ages of the earth; but we have the authority of Mr Lyell for stating, that it is found in contact with, and altering rocks belonging to, the cretaceous period in the eastern Pyrenees.

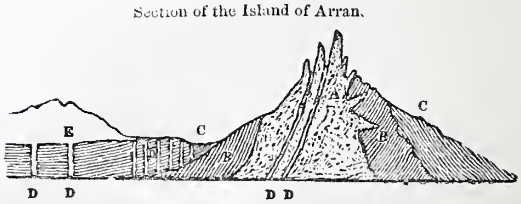
He also mentions the metamorphic character of a limestone containing fossils belonging to the oolite or lias formation, which occurs within a few yards of granite in the Hautes Alpes, near Vizille, in France; and another instance is stated as occurring near Champoleon, of a granite which is observed to overlie the secondary rocks, and producing an alteration which extends about thirty feet downward, diminishing in the beds which lie farthest from the granite.

The granite of Dartmoor, in Devonshire, is now ascertained to be of a later date than the culm-beds of that district which contain the true coal plants, and are therefore regarded as belonging to the carboniferous era.

Granite is also found traversing silurian beds and gneiss, near Christiana in Norway, so that we may conclude although the products of modern volcanoes offer scarcely any marks of similarity in composition with granite, that that rock is of no definite age in the history of the globe; but on the contrary, has been formed at successive periods, but under very different conditions from those which give origin to lavas and some other volcanic productions. Indeed, in investigating the instances where granite comes into contact with, or penetrates the adjacent strata, we cannot help coming to the conclusion that it has been formed under the pressure of the rocks which it penetrates, and altered while these were superimposed upon it in a horizontal or slightly inclined position. We have a beautiful illustration of this in the Isle of Arran.

That island is composed of rocks consisting of trap, granite, red sandstone, conglomerate, and a slight development of the carboniferous formation. The central mass of the southern portion of the island consists of the granitic mountains of Goatfell, and Caim-na-callaich; the former rising to about 3000 feet above the level of the sea. The granite is flanked by precipitous ridges of schistose rocks, in which no organic remains have yet been discovered. The granite is observed to penetrate these schists in the form of veins; on the edges of the schists there are immense deposits of red sandstone and conglomerate, followed by limestone containing many organic remains common to the oldest carboniferous deposits of the main land. The limestone is succeeded by fossiliferous shales, sandstones and coal, and finally by enormous deposits of red sandstone, marl and conglomerate, traversed with innumerable veins of trap and some of pitchstone. These veins penetrate all the rocks from the granite upward. Throughout a great portion of the island, the secondary strata is overlaid by trap rocks. The following diagram will furnish the reader with a better idea than mere description of the conformation of the island.

Section of the Island of Arran.




A Granite. B Schists. C Sandstones, conglomerates, &c. &c. D Trap veins E Overlying trap.

The granitic mass has evidently broken through the upheaved schists by some elevating force after it had become consolidated; and if from the same sandstones and limestones occurring on either flank of the granite, we may infer that they once formed a continuous deposit over the area of the island, after the whole mass of deposition had taken place. But we do not infer that the elevation was sudden; on the contrary, to effect the denudation that has taken place, it must have been of slow progression. That we are correct in supposing that the granitic elevation to the surface is more recent than the deposition of the newest sandstones and conglomerates of the island, is apparent from the remarkable circumstance, that though these conglomerates consist of

quartz, and other fragments of the schists and trap peculiar to the island, we never find the slightest trace of granite entering into the admixture. While the conglomerates were being deposited, it is not possible but that they should also have contained fragments of the granite, had it at that time been exposed to the same agencies which degraded the schists. All the conglomerates that are now aggregating on the coast contain fragments of granite; and immense masses of it are distributed over the island, some at very considerable elevations above the level of the sea, circumstances which strongly prove that the granite was formed prior to the denudation and upheaval of the rocks which flank it. The enormous extent of denudation which must have taken place before Goatfell could have attained granite of its present configuration, leads us necessarily to the contemplation of ages too vast for the human imagination to conceive, if we attribute the waste of the denuding agencies of other ages by anything approximating to those now in operation; but, great as these are in this little insignificant island, how are we lost when we turn our attention to the causes which give origin to the Alpine regions of Switzerland, the Andes of America, or the Himalayas of Hindostan, rising with their snow-clad summits to the elevation of 27,000 feet, or more, above the level of the sea, and exhibiting changes and revolutions which altogether baffle conception, whether we take the amount of time or of alteration into account.

"It is not half a century," says Mr Lyell, "since the doctrine was very general, that all granitic rocks were primitive; that is to say, that they originated before the deposition of the first sedimentary strata, and before the creation of organic beings. But so greatly are our views now changed, that we find it no easy task to point out a single mass of granite demonstrably more ancient than all the known fossiliferous deposits. Could we discover some lower Cambrian strata resting immediately on granite, there being no alterations at the point of contact, nor any intersecting granitic veins, we might then affirm the Plutonic rock to have originated before the oldest fossiliferous strata. Still it would be presumptuous to suppose, that when only a small part of the globe has been investigated, we are acquainted with the oldest fossiliferous strata in the crust of our planet. But even when these are found, we cannot assume that there never were any antecedent strata containing organic remains, which may have become metamorphic. If we find pebbles of granite in a conglomerate of the lower Cambrian system, we may then feel assured that the parent granite was formed before the lower Cambrian formation; but if the incumbent strata be merely silurian or upper Cambrian, the fundamental granite, although of high antiquity, may be posterior in date to known fossiliferous strata."

The greatest granitic masses of Scotland occur chiefly in the county of Aberdeen, which is almost wholly composed of granite and gneiss. A large track of granite occurs, also, between Huntly and Banff, in Banffshire; and patches of considerable extent intersect portions of the counties of Perth, Inverness, and Sutherland. Ben Cruachan, Ben Anca, Ben Slarive, on the south of Loch Etive, and a tract of country on the north of the same loch, are composed of granite. Indeed, if lines be drawn from the head of Loch Awe to Aberdeen, and to the Moray Frith, the greater part of the space included is filled with gneiss, resting irregularly on the granites of Ben Cruachan, Loch Rannoch, Dalwhinnie, Cairngorm, Aberdeen, and Peterhead. In the south of Scotland there are two considerable granitic districts: one on the shores of the Solway Frith to the south-west of Dumfries, and the other in Kirkcudbright, stretching from the south of Loch Doon to a few miles of the shore at Wigton Bay. The western extremities of the isle of Mull, also, consist of granite.

The only granite districts in England are those of the counties of Cornwall and Devon; occurring in several extensive detached patches from the Land's-End to Dunsford, near Exeter.

Granite mountains are in general wild, rugged, and precipitous, and are almost always skirted with other mountains of gneiss or mica slate, the strata of which are highly inclined; but the highest mountains are not to be supposed always composed of this material. On the other hand, granite, composed of the usual crystals of mica, felspar, and quartz, is not so common as was once supposed. Granite, in the Alps and other places, is seen passing into porphyry; and there can be no doubt that that rock and granite are often of the same date.

Granite is a rock frequently of great beauty, and capable of fine polish. It is generally distinctly crystallized,—the crystals in the typical forms being mica, felspar, and quartz; but felspar is often added to the compound, either as occupying the place of mica, or associated with other usual crystals. Other minerals, such as actinolite, chlorite, talc, compact felspar, steatite, and garnet, enter into, and modify the appearance of granite. In colour it varies according to the different hues of the prevailing minerals.

The colours of all the ingredients vary. The felspar is red, greyish white, white, pale flesh-coloured, yellow or green, and is laminar in its structure, by which it is chiefly to be distinguished from the quartz. The quartz is usually clear white, or grey, and sometimes black. The mica is black, white, grey, brown, and of a silvery appearance, splitting readily into thin transparent plates. The hornblende is black. The felspar and mica are always crystallized—the quartz filling the interstitial spaces left by these minerals—but in the cavities of the rock, beautiful crystallized prisms of quartz are not uncommon. The size of the grains or crystals are various in some of the newer veins of granite which traverse the older rock; the crystals are very large, and some of the mica veins some inches across. Granite, according to MacCulloch, may be either composed of two, three, or four ingredients.

*Binary*—*a* Felspar and mica.
*b* Quartz and felspar.
*c* Quartz and hornblende.
*d* Felspar and hornblende.
*Tertiary*—Quartz, felspar, and mica, uniformly blended, or with additional crystals of felspar, and then called porphyritic granite.
*Quaternary*—*a* Quartz, felspar, and hornblende (syenites).
*b* Quartz, felspar, talc, or chlorite.
*c* Quartz, felspar, mica, hornblende, or actinolite (syenite).
*d* Quartz, felspar, mica, and compact felspar or porcelain clay.
*e* Quartz, felspar, hornblende, chlorite, or steatite.

It is evident from those varieties of admixture, that some of them are nearly, if not wholly, allied to some of the members of the trap family, particularly greenstone, which is composed of hornblende and felspar, and that however diversely modified, the granites and traps belong to a common origin. But whether the matter composing these rocks, prior to its having been melted, was derived from previously existing sedimentary rocks, is a question of which we probably have no adequate data to form an opinion upon; but this is certain, from whatever source derived, we have evidence, wherever it is found to have protruded through other rocks, that effects have been produced of the extent or the duration of which shortlived man can form no adequate conception.

*Gneiss and Mica Slate.*—Hardly any real gneiss or mica slate rocks occur in either England or Wales. The mountains in the northwest of Ireland are also composed of these rocks.

They are formed of layers of laminated rock frequently much contorted. Gneiss consists of the same felspathic quartz, and micaceous ingredient as granite; and is often only to be distinguished from it by its laminated structure. Mica slate is less granitic in its appearance, the mica being the predominating mineral, and the felspar wanting; primary limestone or marble, and serpentine, are sometimes associated with these formations, and quartz rock is very abundant. Compared with the other formations which compose the solid frame-work of the globe, they are more indurated, crystalline, and silicious in their composition,—the secondary rocks having a greater variety of arenaceous and calcareous beds, while in the tertiary, loose sands, marls and clays prevail.

"In gneiss, mica, schist, chloride and hornblende schist," says Mr Philip, "the magnitude of the grain is indefinite; and it consequently happens that all of them admit of numerous variations, to which it is useless to give names, from largely granular quartz or even conglomerated gneiss (Zetland) to a fine-grained nearly uniform admixture of mica, quartz, and felspar, mica and quartz, felspar and quartz, (with or without chlorite, hornblende, &c.) In this state these silicious rocks become very similar to certain argillaceous slates, which, in fact, in some cases, seem to bear exactly the same relation to gneiss, mica slate, &c., that common clays do to common sandstones; there is every gradation between them; their origin is undoubtedly similar—it may be even called the same, since one land-flood or sea-storm will form both stratified sands and laminated clays from the same wasted land or broken cliff, according merely to the difference

of circumstances under which the materials were accumulated. Now it is impossible to doubt that the clay slates have been deposited in water; it is equally certain that the gneiss and other felspathic and quartzose rocks which are associated with it, and occasionally with clay slate, are also of aqueous production; and the composition of gneiss, &c, completes the evidence wanted to prove that the primary strata analogous to sandstones and clays were formed from the waste of granitic rocks."

The laminæ of gneiss and mica slate frequently present instances of curvature of the most extraordinary kind. This is not confined to small portions of the rocks, but instances are not uncommon of the whole mass being twisted and bent in a manner that never could have taken place had the rocks always existed in the same indurated manner as at present. Mr Philip considers that the only explanation of this remarkable circumstance is, the agitation of the sea or the soft sediment on its bed by heat; exactly as in the bottoms of steam boilers, the calcareous sediment is formed in irregular undulating laminæ, which appear on a cross section very similar to the flexures in the laminæ of gneiss. This appears to account for those minor flexures; but when, as in such remarkable bendings as occur at Cape Wrath and other places delineated by M'Culloch, we are inclined to suppose that lateral pressure has been applied while the rock was yet in a soft pasty state. This author, whose examination of the gneiss rocks of Scotland is of the most satisfactory character, gives a table in which the primary schists are arranged. Under the term gneiss, he places some rocks which differ from the compound. He considers gneiss as regular which contains at least three of the four minerals, quartz, mica, felspar, and hornblende—irregular when containing compact felspar, or when of irregular composition in other respects. The following is his classification of regular gneiss:—

I. Granitic gneiss, always large grained.
- *a* Composed of quartz, felspar, and mica.
- *b* " quartz, felspar, and hornblende.
- *c* " quartz, felspar, mica, and hornblende.

II. Schistose gneiss, when the structure is foliated like mica slate, or granular like quartz rocks.
- *a* Composed of white felspar and quartz in minute grains, with rare scales of mica (resembles quartz rock).
- *b* Composed of felspar and quartz as above, but with an abundance of mica (so as to resemble mica slate).
- *c* In this the mica is so abundant as to form continuous laminæ.
- *d* In this the mica is predominant, and there are large interposed crystals of felspar.
- *e* Composed of large grains of quartz and felspar, with a little mica.

III. Laminar gneiss, in which each substance occupies a distinct lamina.
- *a* Composed of quartz and felspar.
- *b* " quartz, felspar, and mica.
- *c* " quartz, felspar, and hornblende.
- *d* " felspar and hornblende.
- *e* " quartz, mica, and hornblende.

Mica slate is also classed into three divisions by the same author.

*Division I.* That which consists of mica and quartz.

*Subdivision* 1.—Is simply laminar or foliated.
- *a* Composed principally of continuously laminar mica.
- *b* Composed principally of continuously laminar quartz.
- *c* The mica discontinuous, the quartz granular.
- *d* The mica greenish, and approaching to chloritic schist
- *e* Mica grey, approaching to talcose schist.
- *f* Approaching to clay slate.

The rocks of this division are frequently and remarkably contorted.

*Subdivision* 2.—Granularly laminar.
- *a* Granular quartz with scales of laminar mica.
- *b* Laminar quartz with mica in scattered spots.
- *c* Laminar quartz with distinct scales of mica.
- *d* Laminar quartz with mica in parallel lines, so as to appear fibrous on splitting.
- *e* The mica bent and contorted round the grains of quartz.

*Division II.*—Composed of three or more ingredients.
- *a* With hornblende.
- *b* With felspar (passing into gneiss).
- *c* With chlorite or talc (passing to chlorite or talcose schist).
- *d* With one or more of these ingredients.
- *e* With carbonate of lime.

*Division III.*—Conglomerated, or containing superadded fragments of granite, gneiss, limestone, &c. (In Isla, Garveloch, Rannoch, &c.)

Gneiss and mica slate are undoubtedly the oldest rocks with which geologists have yet become acquainted. And although some writers have contended that they ought to be reckoned equally with granite, as of igneous origin, we consider that there is sufficient evidence in their distinctly stratified character to justify the conclusion that they are the results of aqueous deposition like the fossiliferous strata of later periods.

"The ingredients in these rocks are not in the same condition. In the granite, all is crystallized; each mineral is independently a crystal, or moulded in the cavities left between crystals; the gneiss and mica, mica schist, the felspar, quartz, and mica, are rolled or fragmented masses. The character of worn surfaces of the ingredients, combined with the lamination of the mass, assures us that aqueous agencies have determined the aggregation of gneiss and mica schist; the character of the lamination, or stratification of the mass, assures us that aqueous agencies have determined the aggregation of gneiss and mica slate; the character of the lamination, especially the minute flexures which abound in these ancient rocks, suggests somewhat of peculiarity in the condition of the water; and the internal crystallization of the attrited felspar reveals its origin from the disintegration of granite."—*Penny Cyclopedia.*

These rocks have never been found to contain the least trace of animal or vegetable remains. Mr Lyell seems to think this is no evidence that both may not have existed at the period of their deposition; but the paucity of organic remains, in the earliest formations in which they occur, seems to favour the idea that the globe became gradually fitted for their reception; and if so, that it is reasonable to suppose, there was a period when the conditions of the earth were such as to exclude the possibility of their existence. The idea of the power of heat, of entirely effacing every trace of organic forms in these old rocks, does not seem to us conclusive; we have seen shells and corals perfectly preserved in limestone, after it had been completely calcined in the lime-kiln; and witnessed examples of casts of shells remaining quite entire in ironstone, and shale, which had otherwise been altered by the contact of igneous rocks. There appears therefore every reason to conclude, that the present character of the rocks to which we refer, has been owing to the action of heat. From no organic remains being found in them, that they were deposited before the creation of such had taken place, and probably before the existence of dry land, and that these deposits are of more general occurrence throughout the crust of the earth than any other.

## CHEMISTRY OF INORGANIC NATURE.

There was a time when learned men imagined that all material things were formed of fire, air, earth, and water—the four elements of the Greeks and Romans. This doctrine was first promulgated by Empedocles, a famous philosopher and poet, who flourished some four centuries before the Christian era. So much respected were the opinions of this great man—and he *was* great for the age he lived in—that they were sung in verse by his contemporaries, and have been incorporated into the poetry of all succeeding ages. A charm and an authority thus grew around them; and they stand out in prominent relief among the gods and goddesses of the classic page, as a concentration of that physical knowledge which antiquity has bequeathed to us.

But the doctrine of the "four elements" is not confined to the repositories of classical lore: it has been disseminated far beyond the sphere in which it had its origin. In spite of the strong common-sense philosophy of Bacon, it has struck deep into the general mind, and become entwined with the very texture of common language. The momentum which it attained on the revival of learning has brought it down to our own times, and given it a place in the best dictionaries of our language; and it is much to be feared that it still continues to be regarded by the lords of spondee and double-trochee, as a fair imbodiment of man's highest and brightest conceptions of physical economy.

Although it is not with classical notions that we are here to be engaged, it is perhaps proper to observe that the ancient philosophers did not, in all probability, attach the same precise idea to the word *element* which it bears in the vocabulary of modern science. A more extended and accurate knowledge of matter and its modifications has led to the use of the term as synonymous with "simple substance;" but the crude and meagre guesses about the constitution of matter and its various conditions, which satisfied Empedocles and his followers, are proof enough that their use of the term was much less precise. They observed three conditions of matter—solid, liquid, and gaseous—and they reckoned fire matter of a fourth kind; and, reason-

ing abstractly on the phenomena before them, they arrived at a confused notion that one sort of matter might be transmuted into another, and that all material things were compounded of the "four elements."

"Classical knowledge," however, assists us but a very little in comprehending the economy of nature. The processes by which nature works are discovered only by sober investigation of phenomena, and by patient induction of the facts of experiment and observation. It is in this way that we propose to inquire into the claims of *air, water,* and *earth,* to be reckoned as elements. Let us begin with

### I.—SOME PHYSICAL PROPERTIES OF THE ATMOSPHERE.

The atmosphere, as its name implies, is a spherical mass of gaseous matter, which envelops our globe, and moves with it round the sun—it is the transparent medium in which we live and move, and which supplies us with the breath of life from the first to the last moment of our living existence.

The systematic discussion of the mechanical properties of this great aerial ocean, and the phenomena depending upon them, constitute an interesting and important branch of physical science, under the name of pneumatics. It is not, however, with these that we are to be engaged: our main business is with those properties and adjustments which adapt the atmosphere to perform its great and important functions in the maintenance of animal and vegetable life. To understand the true nature of our inquiry, we must indeed encroach upon the results of pneumatics —we must understand that a material atmosphere does envelop us, and that, like other matter, it is preserved at the earth's surface by the force of gravity. The common-sense evidence which ordinary experience lays before us, is, however, enough for our purpose—enough to convince us that air is matter, and penetrates wherever we can be. That it offers considerable resistance to mechanical force, we learn from the impulse of the breeze on the sails of a wind-mill, or of a ship, and especially from the destructive march of the hurricane. Even the flying of a kite, the blowing of a bellows, and the fluttering of a leaf on an aspen bough, are evidence of the same truth—the materiality of the medium in which we live and have our being. The propagation of sound is another proof that we live not in a void. But for the materiality of the atmosphere the stillness of death would brood over our world. No sound would reach the ear; for sound cannot, like light and heat, propagate itself through vacuous space. A bell struck in the vacuum of an air-pump cannot be heard—the conditions are wanting both for the production and the transmission of sound. Light, too, would lose much of its utility were the atmosphere with its modifying influence withdrawn. The solar radiation would reach us undiffused by an intervening medium, and the great luminary of day would appear a blazing mass suspended in a black sky. No light would penetrate our dwellings except by direct solar radiation or terrestrial reflection. Every shadow would be black, and night would come with instant and total darkness, except when the moon lent a feeble effulgence.

The elasticity which air possesses cannot have escaped the notice of the most careless observer. A blown bladder may be greatly compressed without rupture; but when the compressing force is removed, the air again expands—the particles repel each other and resume their former distances, and the bladder its former dimensions. The force with which these conditions are restored, and which we term *elasticity*, is of considerable energy, and manifests itself with destructive violence when compression is carried too far. The well-known danger of forcing too much air into the hollow globe which serves as a receptacle of force to the air-gun, arises from this cause. Rupture, in cases of this sort, is followed instantaneously by explosion, and the operator has more than once paid the penalty of incaution with his life.

The law of the elasticity of gases generally has indeed been founded upon that of atmospheric air, and is expressed by saying that the volumes of the gases diminish as the pressures to which they are subjected increase. Thus, a portion of air which occupies 100 cubic inches of space, when compressed by a force of one pound, will be compressed to 50 inches when the pressure is doubled, and will expand to 200 cubic inches when the compressing force is reduced to half a pound. This law was first developed in 1662, by the celebrated Dr Boyle; but a new and more accurate demonstration of it was given some years afterwards by a French philosopher of the name of Marriotte, (apparently without being aware that the discovery had been previously made in England); and hence it has come to be recognised as the *law of Marriotte*. It had not been verified for very great pressure till 1825, when Oersted instituted a series of experiments which proved the law to be general, except when certain of the gases approached their points of condensation. It has been proved, however, that atmospheric air may be compressed with a force equal to 12,000 lbs. for every square inch of its surface, without manifesting any deviation from the law, that "the density is in proportion to the compressing force;" and under such a pressure, it may be observed, its density is greater than the density of water.

That air has weight, a very simple experiment serves to prove. A vessel—a glass globe for example—weighs less after it has been exhausted of its air, by means of an air-pump, than it did before; and in like manner its weight is increased by increasing the quantity of air within it. The difference is moreover a very sensible quantity. Supposing the experiment to be made in a room of ordinary temperature, a glass globe, whose capacity is 100 cubic inches, is found to weigh 31 grains less when exhausted of its air than it did before; and hence we conclude, that 100 cubic inches of common atmospheric air taken at the surface of the earth—the surface level of the sea properly—and at a temperature of 60°, weighs 31 grains, (accurately 31·0117 grains; barometer at 30 inches). Compared with water, an equal volume weighs 815 times as much—that is, one cubic foot of water contains as much matter as 815 cubic feet of atmospheric air. Compared with mercury, the weights of equal volumes are in the ratio of 1 to 11065.

If then the weight of such a small portion of air as we are able to subject to direct examination be thus an appreciable quantity, we can have no difficulty in understanding that the aggregate pressure upon the earth's surface, in consequence of the weight of the superincumbent mass of atmosphere in which it is involved, must be great almost beyond name. This it is true must depend on an element which we have not named—the height of the atmosphere. All fluids partake of one fundamental property; they transfer pressure equally in all directions, and as a consequence, the pressure arising from their own weight acts in every direction; and as the particles are supposed to possess perfect freedom of motion at any point, the pressure depends on the weight of the fluid column above that point. At the earth's surface, the last stratum of air sustains the whole weight of the superincumbent mass; at this point, therefore, the air is compressed, and its particles are forced nearer to each other, until their self-repulsion prevents any greater approximation. Hence the density of the air is greatest at the earth's surface—that is, a cubic foot of it, taken at the surface, weighs heavier, and contains more particles, than an equal quantity taken by measure at a greater height in the atmosphere; and the higher we ascend, the greater is this difference; for the density continually diminishes as the height increases. This condition of being less dense we express by the words *more rare*, because the number of particles in a given volume is less, and therefore such a volume would weigh less. At length, as we trace the conditions upward, the superincumbent pressure continually becoming less, and the rarity greater, we *may* arrive at a point where the elasticity is balanced by the mere gravity of the particles, and the atmosphere terminates. At what elevation this occurs, is not certainly known; but from the phenomena of the refraction of light, it is calculated that the atmospheric ocean cannot fall far short of 45 miles in depth. Dr Wollaston has further estimated, from the law of expansion of gases, that it must extend to at least 40 miles, with properties unimpaired by rarefaction. It may, however, be observed, that in speculating upon its extent beyond that distance, a question arises, whether the atmosphere is really limited to the earth? On the supposition that it is not so limited, it would pervade all space, and accumulate about the sun, moon, and planets, forming around each an atmosphere proportionate in density to their forces of attraction. Dr Wollaston has discussed this subject with his usual sagacity, and infers from observations made by himself, in conjunction with Captain Kater, that there is no solar atmosphere. The observations of other astronomers appear to justify the same inference with respect to the planet Jupiter. If then

we admit the accuracy of these conclusions, it follows that our atmosphere extends only to a certain definite elevation beyond the earth's surface—to that elevation where the elasticity becomes so feeble, that the tendency of the particles to separate further from one another is counteracted by the simple force of gravity. The unknown height at which this equilibrium—if such equilibrium exists—between the two forces of elasticity and gravitation takes place, must be the extreme limit of the atmosphere, and may be established by two concurring causes,—the distance between the particles of air when highly rarefied, and the extreme cold which prevails in the higher strata of the atmosphere.*

That the temperature of the atmosphere varies with its elevation can hardly be doubted. Gases permit heat to pass very freely through them, and are little influenced in their temperature by its passage. Applying this to the atmosphere, it is not heated by transmitting the solar rays, but receives its heat from the earth, chiefly by contact. Its temperature becomes thus progressively lower, as the distance of the general mass from the earth increases. Another circumstance which contributes to the same effect is, the increasing tenuity of the atmosphere; for the temperature of rarefied air is less raised by a given quantity of heat, than that of the same portion of air when compressed. This, as elsewhere explained, is owing to the specific heat of the body being increased by rarefaction. The joint influence of these two causes is very perceptible; for, ascending in the atmosphere, we find the temperature diminishing at the rate of about one degree for every 352 feet. The rate of decrease is probably much slower at great elevations, but still there is no reason to doubt that the higher the ascent, the greater the cold experienced. There must consequently be a point of height over every latitude where the thermometer never rises above 32°, and where ice is never liquefied. This point varies with the latitude,—it is highest within the tropics, and descends gradually as we approach the poles. It is designated by geographers as the *snow-line* and *line of perpetual congelation*, and is actually marked off on many of the mountain-ridges scattered over the earth's surface. Its elevation above the sea-level is given in the following table, for every five degrees; that is, for every 300 miles.—*Turner's Chemistry*.

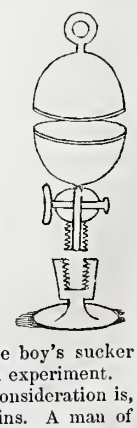
| Latitude. | Height in feet. | Latitude. | Height in feet. |
|---|---|---|---|
| Equator, | 15,207 | 45° | 7,671 |
| 5° | 15,095 | 50 | 6,334 |
| 10 | 14,764 | 55 | 5,034 |
| 15 | 14,220 | 60 | 3,818 |
| 20 | 13,478 | 65 | 2,722 |
| 25 | 12,557 | 70 | 1,778 |
| 30 | 11,484 | 75 | 1,016 |
| 35 | 10,287 | 80 | 457 |
| 40 | 9,001 | 85 | 117 |

In reference to this table it is to be remarked, that in tropical countries, the temperature of the air being nearly uniform throughout the year, the line of congelation is distinct and unvarying; but in countries to the north and south, which have strong contrast of summer and winter, the line rises in summer and falls in winter, and thus becomes broad and less evident. In the breadth of the snow-line, we have the reason of the formation of *glaciers* amid snow-capped mountains, situated in such climates, and around such only. "The snow near the upper part of the broad line, having been only half-thawed in the preceding summer, becomes in winter almost as solid as ice; and in the succeeding summer, vast masses of it, detached by the action of the sun, and of the internal heat of the earth, and loaded with more recently deposited snow, are constantly falling down into the neighbouring valleys within the broad line of congelation; where, being accumulated, and the crevices filled up with snow or with water, which hardens to ice, they form at last the huge glaciers or seas of ice—*mers de glace*—which render certain regions of the earth so remarkable. The falling of the detached masses, called in Switzerland *avalanches*, is what renders the ascent of snow-clad mountains so dangerous and terrific. Around Mont Blanc, in the awful solitudes of the elevated valleys, the avalanches are during the whole summer thundering down almost without interruption." The summer is, moreover, the only time during which the mountain can be ascended, and so precarious is the tenure which the traveller has of safety, that the crack of a pistol-shot, or any considerable agitation of the air, may suffice to set loose masses that would sweep away a whole convoy. Beneath glaciers there is perpetually going on a melting process, and in consequence a stream issues from the bed of every glacier. Such streams are in Switzerland the beginnings of the magnificent Rhine and Rhone.

* For a further explanation of this subject, as regards the limit of evaporation, see p. 167.

Returning to the consideration of the pressure exerted by the atmosphere at the surface of the earth, we may remark that this was first observed by Galileo in the 17th century, and demonstrated by his pupil Torricelli, (1643) to whom science is indebted for the barometer. Torricelli's attention was drawn to the subject by a well-digger in Florence, who applied to him for advice in a case in which he had expected to raise water to an extraordinary height, by means of a sucking pump, and was astonished to find that the water could not be induced to rise higher than 34 feet. The received explanation of the rise of water in a tube, by means of a pump, then was, that *nature abhorred a vacuum*. But this case presented the broad question,—does nature abhor a vacuum only to the extent of 34 feet? The affirmation was too absurd to be admitted, and Torricelli—recollecting the suggestion of his teacher, that the cause of the rise of water in a pump-pipe might be the pressure of the atmosphere—at once concluded, that a column of 34 feet was sufficient to equipoise the air. To verify the correctness of this explanation, he had recourse to direct experiment. He filled a glass tube, three feet long, and closed at one end, with mercury; then inverting it in a basin of the same fluid, the liquid immediately sank about six inches from the top of the tube; thus proving that the pressure of the atmosphere which could support a column of water of about 34 feet in height, could only support a column of mercury of 30 inches. But the heights of these columns are in strict relation to the density of the fluids, namely, $13\frac{1}{2}$ to 1; and their absolute weights for equal diameters are the same—that is, a column of mercury one inch square, and 30 inches long, has the same weight, (15 lbs. nearly) as a column of water of equal base, 34 feet long, and as a column of air of equal base reaching from the sea-level to the extreme limit of the atmosphere.

The conclusion then is, the atmosphere presses upon the surface of our globe with the same force as an enveloping ocean of water of 34 feet in depth, or a covering of mercury 30 inches thick; that is, with a force of 15 lbs. (strictly 14·7 lbs.), upon every square inch of surface. Nothing is exempt from this force any more than from gravitation, from which the pressure has its origin. That we are not sensible of it on our own persons, and on all surrounding objects, is owing to its equality in all directions. If this equilibrium be destroyed, the force becomes remarkably manifest. A steam-boiler, for instance, which is allowed to cool down, while all communication with the external air is shut off, is not unfrequently burst inward by the force. It was this force, moreover, which worked the old atmospheric steam-engine. In this form of engine, the steam was admitted beneath the piston at a pressure equal to the pressure of the atmosphere; and when the piston, which was counterpoised, had reached the top of the cylinder, the steam beneath it was condensed, and a vacuum created, into which the piston was forced down by the atmospheric pressure. Many experiments are shown in the lecture-room to illustrate the same fact. The most common of these, after exhibiting the ascent of water in an exhausted glass tube, is that with the Magdeburg hemispheres. These are two hollow hemispheres of brass, ground so that their edges fit together perfectly air-tight. One of them has a hollow stem fitted with a stop-cock and screwed at the end, so that the apparatus may be attached to an air-pump and exhausted. When this has been accomplished, and the stop-cock turned, the apparatus—being then removed from the air-pump, and a proper handle attached—is given into the hands of two muscular individuals to try their strength in pulling the hemispheres asunder. That this is rarely accomplished is readily understood, when it is considered that they are held together by as many times fifteen pounds as there are square inches on their surface. The boy's sucker is upon the same principle, and makes as good an experiment.



Perhaps the most astonishing element of this consideration is, the enormous load which the human body sustains. A man of ordinary stature exposes about 15 square feet or surface, so that

the amount of atmospheric pressure upon him amounts to 14 tons. This he sustains without the slightest inconvenience; and the explanation is, that every cavity of his body is distended with aëriform matter of the same elastic force. The human structure may be regarded as a collection of open and close vessels, all of which are "packed in fluids." On the closed parts the pressure is equal inside and outside, and in case of such parts as are open, there is equilibrium between the internal and external air. Indeed, were it not for this same atmospheric pressure, which at first sight may seem an inconvenience, the finer vessels of the animal body would infallibly be ruptured and life destroyed, by the elasticity of the fluids within them. That we are able to move about under our atmospheric load, without being conscious of its existence, is owing to the equality of its action, and the perfect mobility of the particles through which it is transmitted; for, like all fluids, the gravity of air presses upward as well as downward, and laterally, and in every direction.

We have already remarked that the barometer is the bequest of Torricelli to science. This is essentially nothing more than a glass tube of about 33 inches long, with its open end placed in a cup of mercury. Water is sometimes employed, but the tube then requires to be about as many feet in length. The instrument is prepared thus:—First, fill the tube with the liquid, then having covered the open end with the finger, carefully invert it and place it under the surface of the mercury in the cup. Upon removing the finger the mercury will fall a certain distance, leaving a column in the tube of a height corresponding to the atmospheric pressure at the time. A scale being then attached, the instrument is complete.

Several modifications of the barometer are in use; but their theoretical action is the same as the straight tube barometer described, and none of them are better.

From causes which are not well understood, and which we cannot in the mean time wait to consider, the barometer informs us that the atmospheric pressure is not constant. At the equator, the mercury is at its maximum height at 9 o'clock in the morning,—past this hour it becomes less till 4 in the afternoon, when it reaches its minimum. It again ascends till 11 at night, when it reaches its second maximum, and once more descends till 4 in the morning, after which it reascends till 9. Thus, every day, the mercurial column is at its lowest elevation at 4 o'clock in the morning, and afternoon; and at its greatest, at 9 in the morning, and 11 in the evening. These periodic variations are small, being calculated at less than $\frac{1}{12}$ and more than $\frac{1}{13}$ of an inch by Humboldt; (namely, $\frac{7874}{100000}$ inch). In Europe, they are nearly obliterated by changes of atmospheric pressure depending upon accidental causes, which at the equator are nearly absent. It is upon these changes that we found the indications of the barometer as a weather-glass,—experience having pointed out that the weather is commonly fair and calm when the mercury is high, and wet and stormy when the mercury descends. As far as the horary variations can be observed in our northern latitudes, the maximum in winter appears to be at 9 in the morning; the minimum at 3 in the afternoon; and the second maximum at 9 in the evening. In the summer, the maximum elevations are at 8 in the morning, and 11 at night; the minimum being at 4 in the afternoon. In spring and autumn, the times of these variations are intermediate with those of summer and winter.—*Dr Golding Bird.*

As a column of 30 inches mercury answers to a pressure of 15 lbs. to the square inch, a fall of the mercurial column of an inch answers to a diminution of pressure of $\frac{1}{2}$ lb. on the square inch. Thus, if the barometric column stands at 29 inches, the atmospheric pressure is $14\frac{1}{2}$ lbs. instead of 15 lbs., and so on of all similar variations. There is, therefore, no difficulty in understanding why persons of weakly constitutions often feel considerable discomfort from sudden changes of the weather: the barometric oscillations which we experience in this country are considerable, often occasioning, in the course of a few hours, a change of pressure upon our bodies of not less than a ton weight.

We shall next direct attention to the chemical constitution of our atmosphere, and examine the subject a little more strictly.

## ANATOMY AND PHYSIOLOGY.

### CHAPTER IX.

#### THE BONES.

The important offices fulfilled by bone in the animal economy, and its almost imperishable nature, have always given it importance in the eyes of the philosopher; while the phrases in use in every language bear testimony to the high place it holds in popular estimation. We see it forming a frame-work to give shape and support to the body, cases and cages to protect the more delicate organs, and levers by which locomotion is performed, and force exerted. Again, we find it among the tombs, successfully resisting agencies which had reduced the softer parts of our bodies to dust a century before; and we speak of laying our bones in the grave as if they constituted the essential element of our frames.

In order to be fitted for the purposes above referred to, the bones, whose union constitutes the skeleton, are at once hard and tough; hard to resist external violence, and tough to give them a degree of elasticity. This hardness we shall find to depend on the large proportion of inorganic matter, especially of lime, which enters into the composition of bony tissue. This chemical constitution also accounts for its durability. Let us, in this article, devote our attention to what is called its *general* anatomy; that is to say, its physical properties, and chemical composition; its organization as a part of the living body, and any peculiarities that may appear worthy of the notice of the unprofessional reader.

The most remarkable property in bone, and that which first strikes us, is its great *hardness*, as compared with other parts of the body. It is, indeed, the only part of the body entitled to be called hard,—cartilage, which comes next to it, admitting of being cut with a knife. This hardness increases with old age, from the greater proportion of earthy matter which is deposited into its interstices, and it is much less in children of tender years. Its *specific gravity* is greater than that of any other animal substance. Its *colour* in the living body is a pale roseate tint, inclining in young children to red, and in old age to a yellowish white. It assumes a beautiful white colour after having been frequently boiled, or long steeped in water, till the oily and sanguine fluids which pervade it have been entirely removed. Bone is very feebly translucent,—even in thin plates transmitting only a slight quantity of light. It is, however, flexible and elastic. The ribs afford a good example of this, as any one may satisfy himself by compressing his chest with his two hands; and many a one has to thank this quality for his escaping with impunity from the pressure of a dense crowd. The elasticity of the bones frequently saves them from fracture, and lessens the shocks which they convey to the brain, and other soft textures which they support and defend.

Bones assume every variety of shape, as might be expected from the various uses made of them in such a complex machine as the skeleton. These varieties have been reduced by anatomists to four classes; the long or cylindrical, the broad or flat, the short or round, and the mixed or irregular. The long bones are distinguished by their length, which greatly exceeds their other dimensions. They are found only in the extremities, and are adapted for locomotion, and for sustaining the weight of the body. They are never exactly cylindrical, being smallest about the middle, and enlarged at each end where they are jointed to one another. The broad or flat bones are thin, and generally somewhat arched, being fitted to protect some more delicate organs; the best specimens of them are those forming the cranium, and protecting the brain. The short bones are of irregular figures, but are all somewhat roundish; they are found in the wrist, and the instep of the foot. The mixed or irregular bones are sometimes classed along with the short; but it is better to

place them separately. The bones forming the spine are the best examples of these, as combinations of long and short bones. The ribs, and bones of the pelvis, may, perhaps, be also arranged with them, as combining the characters of the long and flat.

We shall find that the different bones present points for demonstration of various kinds. They have surfaces which may be rough or smooth, for the attachment of the softer parts, or to allow these to play over them,—have hollows for the reception of muscles, or other organs,—they have grooves for tendons to run in, or for blood-vessels to lie in,—they have holes for vessels and nerves to pass through,—they have articular surfaces; rough if the joint is to be immoveable; smooth if it be to admit of motion; and they have *processes*, or projecting points, to which particular fibres, of muscle, or of ligament, are to be connected.

If we prepare bones by careful steeping and drying, so as to remove all the oily matter from out of them, and then saw them up, or break them, we shall observe the density of their tissue to differ much in different parts. The outer part is much harder and denser, than the internal part, and is called the compact substance. The internal part is of a looser texture, and is called the cancellated, (that is, cellular,) or spongy substance. These tissues are arranged differently in the different orders of bones.

In the flat bones, the compact substance is arranged into two layers, separated by a thin layer of cancellated structure, through which the blood-vessels which nourish the bone run. When the bone is very thin, the two outer layers are in contact, or appear compressed into one, and the intermediate layer has disappeared. In the round bones, there is a very thin layer of compact tissue on the outside, while the internal part is composed of spongy tissue. In consequence of this predominance of spongy tissue, and consequently of blood-vessels, the round bones are much more liable to inflammation than any of the others. The long bones consist of three parts—a shaft and two extremities. The shaft consists of very dense compact tissue externally, becoming loose internally, and having a canal running through it nearly from end to end; while the extremities are of the same structure with the short bones. This canal makes the bone much stronger than if it were solid, with the same quantity of material, because its diameter is thus much greater; a principle which is understood and acted on by engineers, who make hollow pillars and shafts to gain additional strength without additional expense of metal.

The canal which runs through the long bones is lined with a delicate membrane, in which is contained the medulla or marrow; hence it is called the medullary canal. The medulla is in the young chiefly bloody; in older persons it is oily; and it is put into the canals, not to oil the bones, as many erroneously suppose, but because there is no empty space permitted in the body, and fatty matter is the lightest that could be used for filling them. Besides, the marrow serves the same purpose as the fat in other parts of the body; it is a store of nourishment whence the body can be supported, when unable to take any nourishment from without. In fevers, for instance, when the patient scarcely tastes food for perhaps a fortnight or three weeks, he is maintained on the superfluous parts of his own body; and hence the sunken cheeks and shrunk shanks of such a sufferer when beginning to recover. That this marrow is not of any use to the bone itself is sufficiently proved by the fact, that in birds there is none; but their bones are very thin, and the canals large in order to be light, and instead of marrow they are filled with air, by communications with the windpipe leading to the lungs. There is a common notion that the marrow is exceedingly sensible, and it is remarked "how painful the application of the saw must be in amputation, from its tearing its way through the marrow." Now, the fact is, that the marrow is very little, if at all sensible; and all the pain felt in sawing the bone is a sort of jarring communicated to the soft parts which have been already divided.

The irregular bones, resembling in shape two or more of the preceding orders, have some of their parts, generally their bodies, resembling the round bones; and others, the processes, resembling the long and flat.

The animal and earthy parts of bone can be easily separated, and demonstrated in a separate state. If a piece of bone be immersed for a day or two in diluted muriatic (hydrochloric) acid, the earthy part will be completely dissolved out, and the animal part will be left; yet the bone will still have the same size and the same shape,—so intimately are the two different materials blended together. If it be now dried and weighed, it will be found to have lost nearly two-thirds of its original weight—the loss consisting of the earthy particles. The substance now obtained is the cartilage of bone, which is very nearly the same in composition as the cartilage which we find in the body, ready formed by nature. It is much softer than bone, but harder than any other of the soft parts; it is highly elastic, and if compressed or bent, speedily regains its original shape. When dried, it assumes a darker colour, and becomes hard and tough, translucent, and very like horn. When boiled, this substance is nearly all dissolved, yielding a fine transparent jelly; and it was a knowledge of this property which suggested to Papin the invention of his digester, in which, by boiling bruised bones under strong pressure, the jelly is obtained, and a large quantity of strong soup is made from what would otherwise be entirely worthless. The earthy part of the bone is demonstrated in a different manner. If a bone be put into a clear fire, and heated to redness, the animal part is entirely consumed, and a white friable earth is left behind. This earth consists almost wholly of lime, in combination with phosphoric and carbonic acids. It is on account of their containing the former acid, that phosphorus is obtained from calcined bones. There are minute portions of other salts in the earthy part of bone, but these need only be named in a subsequent table. When a bone has been thus burned, and is weighed, it will be found above one-third lighter than at first, the loss consisting of the gelatinous part. As was remarked of the gelatinous part when obtained by itself, so also the earthy part has exactly the original shape of the bone, and the most minute bony threads of the cancellated texture are still seen existing.

It was long believed that fat, or oil, was an essential part of bones, but that is now known not to be the case; for, the greasy appearance which bones are apt to have does not belong to themselves, but is the consequence of the marrow transuding through them after death.

The bones are covered by a dense membrane called the Periosteum, which adheres strongly to them, serves to convey the blood-vessels to them, and sends prolongations into all the little holes which exist in great number on their surfaces. It also serves as the medium for the attachment of tendons and ligaments to them, having those parts in a manner interwoven and confounded with its outer surface. The periosteum has also a considerable share in the growth of young bones, and in the reparation of old ones, when fractures or other injuries may have rendered that necessary.

When the bones touch one another, and are moveable, they are particularly smooth, and their surfaces are adapted to one another by corresponding prominences and concavities. In addition, to obviate friction they are covered at these places with what is called gristle, or cartilage. Cartilage is intermediate in hardness to bone, and what are properly called the soft parts—it is firm and resisting, and yet it has a great deal of elasticity. In some parts of the body there are cartilages serving for continuations to bones, such as those which continue the ribs, and connect them to the breast-bone, and they are exactly similar to bones from which the earthy part has been dissolved by an acid. But the cartilaginous crusts which cover the articular ends of bones are of a very beautiful and peculiar structure. If a piece of bone be sawn up towards its articular end, till all but cut through, and then the remaining part, and the cartilage covering it, be torn asunder, the cartilage will be found to present an infinity of fibres set perpendicularly on the surface of the bone. When a portion of bone with its articular cartilage has been macerated in water for some weeks, the cartilage is found to have lost its smooth surface and its cohesion, and looks exactly as if the bone had been covered with a bit of white velvet. It will now be obvious that, when pressure is made on the ends of the fibres, they yield by bending a little sideways, but are prevented from yielding much, by the closeness with which they are set together. In effect, the result is just what is seen on a larger scale, if the finger be pressed against the flat surface of a common clothes-brush, the bristles bending a little sideways, and so presenting an indentation on the surface.

As bones are living parts, they of necessity are provided with blood-vessels and nerves. On the surface of every bone may be remarked an infinity of minute pores, into which small blood-vessels run. If the surface of a bone be exposed by an injury in the living body, it will be seen to bleed, and it can be coloured artificially in the dead body, in a manner which will be explained

in the article on the circulation. This coloration, however, is practicable only in young subjects, where a great flow of blood takes place to the bones, to provide material for their growth; in adult years, when they have reached their full size, and have become hard and compact, much less blood, in proportion, circulates through them. There is another very curious way in which the vascularity of young bones can be demonstrated, by making the blood itself the vehicle of the colouring matter with which they are to be injected. If a young animal be fed for a fortnight or so, on food in which a proportion of chopped madder is mixed, the colouring principle of the madder will pass into its blood, arrive in its bones, and there chemically combine with the lime, tinging the bones of a beautiful rose-colour, which is permanent, even after the bones have been cleaned and well washed in pure water. The nerves which are distributed to bones are very trifling, so that in the healthy state they may be said to be almost insensible; but when they become inflamed, their sensibility is so much exalted, that the slightest touch causes excruciating agony.

The formation and growth of bones is an exceedingly interresting subject, but one that cannot well be studied except in the museum, where there are preserved abundant specimens of young children in every different period of fœtal life. In the fœtus, cartilage serves as a substitute for bone at first, and about the sixth week after conception, earthy matter begins to be deposited in it. In the flat bones it is at first deposited in the centre, and extends in lines radiating to the circumference, forming a delicate net-work like a bit of lace; and layer is superadded upon layer, until the necessary degree of thickness is obtained. In the round bones, ossification proceeds from the centre to the circumference. In the long bones, ossification commences at the middle of the shaft, and extends outward gradually to near the ends, when it stops. At a period soon after birth, the ends of the long bones begin to ossify separately, in their centres, in the same way that the short bones do, and they continue separated from the shafts of the bones by a layer of cartilage, till the 15th, 16th, or even the 18th year. Hence children should on no account be rudely pulled about, or twisted about the limbs; as the ends of the bones are apt to be thus twisted off—an accident which, if it do not occasion the loss of the limb, will at least produce incurable lameness.

The chemical composition of human bone, deprived of its blood, oil, and periosteum, is thus given with great minuteness by the celebrated Swedish chemist, Berzelius:—

| | |
|---|---|
| Cartilage and gelatine (soluble in water), | 32·17 |
| Blood-vessels, | 1·13 |
| Fluoride of calcium, | 2·00 |
| Phosphate of lime, | 51·04 |
| Carbonate of lime, | 11·30 |
| Phosphate of magnesia, | 1·16 |
| Soda, with a very little muriate of soda and water, | 1·20 |
| | 100·00 |

The account which has now been given of bone, as a tissue, is applicable, with trifling variations, not only to those of man, but of all the other mammalia, and of birds. In the arrangement of the bones, however, every species differs from the rest, according to the purposes which its body and limbs are intended to serve. The bones united in their places constitute the skeleton.

## BIOGRAPHY.

### LEONARD EULER.

Leonard Euler was one of the most celebrated mathematicians of the 18th, or perhaps of any other century. He was a native of Bale, and was born April 15, 1707. The years of his infancy were passed at Richen, where his father was minister. He was afterwards sent to the university of Bale; and as his memory was astonishingly retentive, and his application regular, he performed his academical tasks with great rapidity; and all the time that he saved by this was consecrated to the study of mathematics, which soon became his favourite science. The early progress he made in this branch of study, added fresh ardour to his application; by which he likewise obtained a distinguished mark of the attention and esteem of professor John Bernoulli, who was then one of the most eminent mathematicians in Europe.

In 1723, M. Euler took his degree as master of arts; and delivered on that occasion a Latin discourse, in which he drew a comparison between the philosophy of Newton and the Cartesian system, which was received with the greatest applause. At his father's desire, he next applied himself to the study of theology and the oriental languages; and though these studies were foreign to his predominant propensity, his success was considerable even in this respect: however, with his father's consent, he afterwards returned to mathematics as his principal object. In continuing to avail himself of the counsels and instructions of M. Bernoulli, he contracted an intimate friendship with his two sons, Nicholas and Daniel; and it was chiefly in consequence of these connexions that he afterwards became the principal ornament of the philosophical world.

The project of erecting an academy at Petersburg, which had been formed by Peter the Great, was executed by Catharine I.; and the two young Bernoullis being invited to Petersburg in 1725, promised Euler, who was desirous of following them, that they would use their endeavours to procure for him an advantageous settlement in that city. In the mean time, by their advice, he made close application to the study of philosophy, to which he made happy applications of his mathematical knowledge, in a dissertation on the nature and propagation of sound, and an answer to a prize question concerning the masting of ships; to which the Academy of Sciences adjudged the accessit, or second rank, in the year 1727. From this latter discourse, and other circumstances, it appears that Euler had very early embarked in the curious and useful study of naval architecture, which he afterward enriched with so many valuable discoveries. The study of mathematics and philosophy, however, did not solely engage his attention, as he in the mean time attended the medical and botanical lectures of the professors at Bale.

Euler's merit would have given him an easy admission to honourable preferment either in the magistracy or university of his native city, if both civil and academical honours had not been there distributed by lot. This being against him in a certain promotion, he left his country, set out for Petersburg, and was made joint professor with his countrymen Hermann and Daniel Bernoulli, in the university of that city.

At his first setting out in his new career, he enriched the academical collection with many memoirs, which excited a noble emulation between him and the Bernoullis; an emulation that always continued, without either degenerating into a selfish jealousy, or producing the least alteration in their friendship. It was at this time that he carried to new degrees of perfection the integral calculus, invented the calculation by sines, reduced analytical operations to a greater simplicity, and thus was enabled to throw new light on all the parts of mathematical science.

In 1730, Euler was promoted to the professorship of natural philosophy; and in 1733, he succeeded his friend D. Bernoulli in the mathematical chair. In 1735, a problem was proposed by the academy, which required expedition, and for the calculation of which some eminent mathematicians had demanded the space of some months. The problem was undertaken by Euler, who completed the calculation in three days, to the great astonishment of the academy: but the violent and laborious efforts that he made to accomplish it, threw him into a fever, that endangered his life, deprived him of the use of his right eye, and which afterwards brought on a total blindness.

The Academy of Sciences at Paris, which in 1738 had adjudged the prize to his memoir Concerning the Nature and Properties of Fire, proposed for the year 1740 the important subject of the Tides of the Sea—a problem whose solution comprehended the theory of the solar system, and required the most arduous calculations. Euler's solution of this question was adjudged a masterpiece of analysis and geometry; and it was more honourable for him to share the academical prize with such illustrious competitors as Maclaurin and Daniel Bernoulli, than to have carried it away from rivals of less magnitude. Seldom, if ever, did such a brilliant competition adorn the annals of the academy; and perhaps no subject, proposed by that learned body, was ever treated with such force of reasoning and accu-

racy of investigation, as that which here displayed the philosophical powers of this extraordinary triumvirate.

In the year 1741, Euler was invited to Berlin to direct and assist the academy that was there rising into fame. On this occasion he enriched the last volume of the Miscellanies (Melanges) of Berlin with five memoirs, which form an eminent, perhaps the principal, figure in that collection. These were followed, with amazing rapidity, by a great number of important researches, which are dispersed through the memoirs of the Prussian academy; a volume of which has been regularly published every year since its establishment in 1744. The labours of Euler will appear more particularly astonishing, when it is considered that, while he was enriching the academy of Berlin with a profusion of memoirs, on the deepest parts of mathematical science contained always under some new points of view, and often replete with sublime truths, and sometimes discoveries of great importance, he still continued his philosophical contributions to the Petersburg academy, whose memoirs display the marvellous fecundity of his genius.

In 1760, the Russian army, under General Tottenberg, penetrated into the Marche of Brandenburg, and pillaged a farm which Euler possessed near Charlottenberg. As soon as the Russian general was informed of the event, he immediately repaired the loss by a large sum; and, upon giving notice of the circumstance to the Empress Elizabeth, she added to the indemnity a present of 4000 florins. This act of generosity had, no doubt, a powerful effect in attaching Euler to the Russian government, which, notwithstanding his absence, had always paid him the pension which it granted him in 1742.

Having received an invitation from Catharine II., he obtained, in 1766, with considerable difficulty, permission from the king of Prussia to return to Petersburg, where he wished to pass the remainder of his days; but soon after his return, he was seized with a violent disorder, which ended in the total loss of his sight: a cataract, formed in his left eye, which had been essentially damaged by the loss of the other eye, and too close an application to study, deprived him entirely of the use of that organ. It was in this distressing situation that he dictated to his servant—a tailor's apprentice, who was absolutely devoid of mathematical knowledge—his Elements of Algebra; which, by their intrinsic merit in point of perspicuity and method, and the unhappy circumstances in which they were composed, have equally excited the wonder and applause of the learned. This work, though purely elementary, plainly exhibits the proofs of an inventive genius; and it is perhaps here alone that we meet with a complete theory of the Diophantine analysis.

About this time M. Euler was honoured by the Academy of Sciences at Paris with the place of one of the foreign members of that learned body; after which, the academical prize was adjudged to three of his memoirs, Concerning the Inequalities in the Motions of the Planets. The two prize questions proposed by the same Academy for 1770 and 1772, were designed to obtain from the labours of astronomers a more perfect Theory of the Moon. M. Euler, assisted by his eldest son, was a competitor for these prizes, and obtained them both. In this last memoir, he reserved for further consideration several inequalities of the moon's motion, which he could not determine in his first theory, on account of the complicated calculations in which the method he then employed had engaged him. He afterwards revised his whole theory, with the assistance of his son and Messrs Krafft and Lexell; and pursued his researches till he had constructed the new tables, which appeared, together with the great work, in 1772. Instead of confining himself, as before, to the fruitless integration of three differential equations of the second degree, which are furnished by mathematical principles, he reduced them to the three ordinates which determine the place of the moon: and he divided into classes all the inequalities of that planet, as far as they depend either on the elongation of the sun and moon, or on the eccentricity, or the parallax, or the inclination of the lunar orbit. All these means of investigation, employed with such art and dexterity as could only be expected from a genius of the first order, were attended with the greatest success; and it is impossible to observe without admiration, such immense calculations on the one hand, and on the other the ingenious methods employed by this great man to abridge them, and to facilitate their application to the real motion of the moon. But this admiration will become astonishment, when we consider at what period and in what circumstances all this was effected. It was when our author was totally blind, and, consequently, obliged to arrange all his computations by the sole powers of his memory and his genius: it was when he was embarrassed in his domestic affairs by a dreadful fire that had consumed great part of his substance, and forced him to quit a ruined house, every corner of which was known to him by habit, which in some measure supplied the want of sight. It was in these circumstances that Euler composed a work which alone was sufficient to render his name immortal.

Some time after this, the famous oculist Wentzell, by couching the cataract, restored sight to our author; but the joy produced by this operation was of short duration. Some instances of negligence on the part of his surgeons, and his own impatience to use an organ whose cure was not completely finished, deprived him a second time and for ever of his sight,—a relapse which was also accompanied with tormenting pain. With the assistance of his sons, however, and of Messrs Krafft and Lexell, he continued his labours: neither the infirmities of old age, the loss of his sight, nor the acuteness of the pain, could quell the ardour of his genius. He had engaged to furnish the Academy of Petersburg with as many memoirs as would be sufficient to complete its acts for 20 years after his death. In the space of 7 years he transmitted to the Academy above 70 memoirs; and above 200 more, left behind him, were revised and completed by a friend. Such of these memoirs as were of ancient date were separated from the rest, and form a collection that was published in the year 1783, under the title of Analytical Works.

The general knowledge of our author was more extensive than could well be expected, in one who had pursued, with such unremitting ardour, mathematics and astronomy as his favourite studies. He had made a very considerable progress in medical, botanical, and chemical science. What was still more extraordinary, he was an excellent scholar, and possessed in a high degree what is generally called erudition. He had attentively read the most eminent writers of ancient Rome; the civil and literary history of all ages and all nations was familiar to him; and foreigners, who were only acquainted with his works, were astonished to find in the conversation of a man, whose long life seemed solely occupied in mathematical and physical researches and discoveries, such an extensive acquaintance with the most interesting branches of literature. In this respect, no doubt, he was much indebted to a very uncommon memory, which seemed to retain every idea that was conveyed to it, either from reading or from meditation. He could repeat the Æneid of Virgil, from the beginning to the end, without hesitation, and indicate the first and last line of every page of the edition he used. He carried on his mind the most complicated calculations. With the design of instructing his grandchildren in the extraction of roots, he formed a table of the first six powers of all numbers up to 100, and he recollected them with the utmost accuracy.

Several attacks of vertigo, in the beginning of September, 1783, which did not prevent his computing the motions of the ærostatic globes, were however the forerunners of his mild passage out of this life. While he was amusing himself at tea with one of his grandchildren, he was struck with an apoplexy, which terminated his illustrious career at 76 years of age.

M. Euler's constitution was uncommonly strong and vigorous. His health was good; and the evening of his long life was calm and serene, sweetened by the fame that follows genius, the public esteem and respect that are never withheld from exemplary virtue, and several domestic comforts, which he was capable of feeling, and therefore deserved to enjoy.

The catalogue of his works has been printed in 50 pages, 14 of which contain the manuscript works.—The printed ones consist of works published separately, and works to be found in the memoirs of several Academies, viz., in 38 volumes of the Petersburg Acts (from 6 to 10 papers in each volume);—in several volumes of the Paris Acts;—in 26 volumes of the Berlin Acts (about 5 papers to each volume);—in the Acta Eruditorum, in 2 volumes;—in the Miscellanea Taurinensia;—in vol. 9 of the Society of Ulyssingue;—in the Ephemerides of Berlin;—in the Memoires de la Société Œconomique for 1766;—and in the Philos. Trans. by seven memoirs, from vol. 44 to vol. 62.

# LINEAR PERSPECTIVE.

## CHAPTER I.

1. *Linear Perspective* may be defined to be the drawing of objects in their exact proportions, with respect to height, length, and breadth, as they appear to the eye when placed in any position. This may be illustrated by placing a pane of glass, or other transparent substance betwixt the eye and an object, and by keeping the eye steady, and tracing the different lines upon the object; if these lines be distinctly marked on the transparent plane, there would be a *linear perspective* view of the object.

2. It is necessary for the person commencing to learn perspective—if he has not got a previous knowledge of mechanical drawing—to understand the use of the instruments commonly used. We will here in the first place explain some of these, and show the manner of using them.

The *drawing-board* is generally made of deal, of a size according to the intended use. We would here recommend one for drawing perspective of about two feet nine inches, or three feet long, by two feet or two feet four inches broad, made of 1 inch or $1\frac{1}{4}$ inch stuff neatly planed and clamped at the edges to keep it from warping. The paper might be fastened upon it, either by drawing-board pins, which is a very good and the most expeditious method, or by sealing wax, or by paste, which is done in the following manner:—Having cut the paper to the size required, wet the back of it with a sponge dipped in clean water, passing it over several times, and leaving it a short time till the water is absorbed, and the paper lies flat; run a rim of paste round the edge, about three quarters of an inch wide; then turn the wetted side of the paper downward on the drawing-board, and press the pasted rim close to the board with a paper knife, or some hard substance, pressing as much of the paste out as possible, that the paper may adhere firmly to the board. The face of the paper should be then wetted in the centre with a sponge, taking care not to pass it on the pasted rim; without this precaution, the centre would be dry before the edges, and the paste would not hold.

The best sort of drawing-boards are those made in a pannel form; in these, there is an outside frame rebated on the inside, into which there is a moveable pannel fitted, also rebated, to allow of the pannel coming nearly flush with the upper surface of the frame. The paper is placed upon this pannel, and then put into its place, where it is fastened by two pieces of wood in the back. This is undoubtedly the best sort of drawing-board, as it keeps the paper stretched, and answers well for drawings which have a deal of minute work about them, and also for colouring.

The next instrument is the T *square*, which is so well known that we would just recommend it to be made straight and strong, not to bend when drawing near its end; those made with a screw for drawing lines at any inclination, are mostly preferred. There are also small pieces of mahogany of a right-angled triangular form, called *set squares*, which by moving along the edge of the T square, lines can be drawn at angles for which the squares are made—those with 45° and 60° are very useful.

*Compasses* are very useful instruments in mechanical drawing: they should be fine pointed, and move freely at the joint, which should not however be too slack; for then a little compression might move them from their position. Those with fixed legs are called dividers. When the moveable leg is taken out, there is a leg which can be put into its place, having a piece of lead pencil fastened into it, for drawing circular lines in lead, and also another for circular ink lines.

*Drawing-pens* are very useful instruments for drawing lines in ink, after being marked out with lead. The handle is made mostly of brass or ivory, having two steel prongs on the one end, which can be brought close or widened (betwixt which the ink is placed), by means of a screw, for drawing the lines fine or broad. There are also *bow-pens*, for drawing small circles in ink, which are very useful, and similar ones for drawing lead lines.

*Parallel rulers* are for drawing parallel lines; they are generally made of two pieces of wood, connected by two pieces of brass, fastened to them near the ends, allowing the wood to move freely: by holding on or pressing upon it, the other can be moved, and it is still held in its parallel position by the pieces of brass. Parallel rules moving on rollers are to be preferred.

These instruments with scales, and a few others occasionally used, are those employed in mechanical drawing; those used in perspective will be described farther on. It may be remarked, that there are cases or boxes of instruments containing compasses, drawing-pens, scales, &c. of different prices, from a few shillings to a number of guineas, to be got in almost every town of note in the three kingdoms—the student by seeing them applied will learn their use far better than by a written description.

3. It is presumed that the student is acquainted with practical geometry—raising perpendiculars, describing squares, triangles, circles, ellipses, pentagons, hexagons, &c.—if not, we would recommend him to learn that in Bonnycastle's Mensuration, or some other work, as there are many, and it would therefore be useless to enter upon the subject here.

4. There are five ways in which mechanical drawings are generally done:—1st, The *ichnographic* or *ground plan* of an object is the seat of the different parts, showing their correspondence, situation and magnitude, without any reference to the height. 2nd, The *orthography* or *elevation*, which is the appearance any object would present, if an eye could view every part perpendicularly. 3rd, *Sections*—these are cuts made through the object showing its internal arrangements—if the section be parallel to the front, it is called a *longitudinal section*, and if from front to rear, a *transverse* or *lateral section;* any other is called an *oblique section*. 4th, The *scenographic*—this is the representation of objects as they appear to the eye when in any position, or the *perspective view*—the scenographic is better applied to perspectives of objects; as houses for instance, when scenery is introduced. 5th, The *development*—this is the representation of any circular, elliptical, or polygonal figure, &c., when taken and spread out upon a plane, thereby giving the appearance of an orthographic projection or elevation. Having gone thus far, we will begin now and explain some of the fundamental parts of the science.

5. If a person stand at the middle of one end of a long road, which is supposed horizontal, straight, and of a uniform breadth, the sides will seem to approach nearer and nearer to each other, as they are farther from his eye; and if the road be very long, the sides of it at the farthest end will seem to meet; and there an object that would cover the whole breadth of the road, and be of a height equal to that breadth, would appear to be a mere point.

*Fig.* 1.

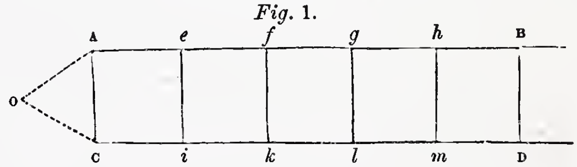
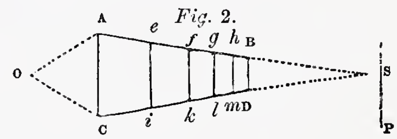



*Fig.* 2.

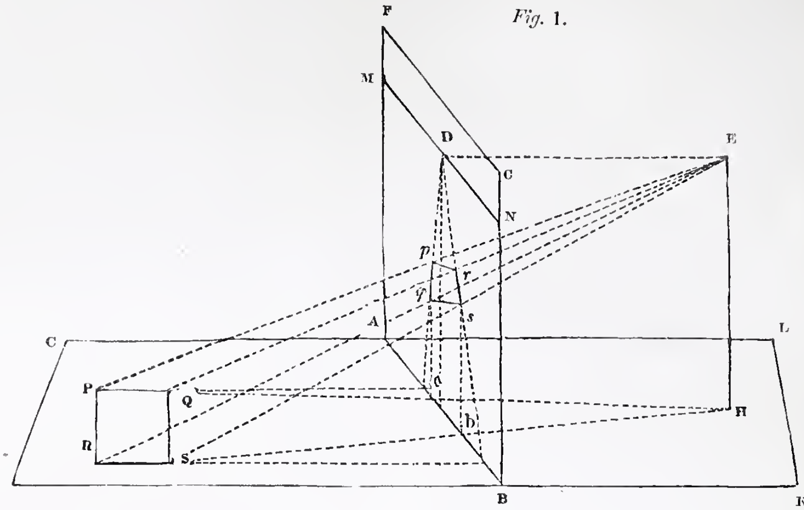



If A B and C D fig. 1. be two parallel sides of a road, and O the place of the observer—suppose the road to be divided into squares, A C *i e*, *e i k f*, &c., the person standing at O will see these two sides, as if they were gradually approaching towards one another, as in fig. 2; and the squares will seem to diminish in size as they are farther from the eye—so that the first square A C *i e*, fig. 1. will appear as A C *i e*, fig. 2.; the second square *e i k f*, fig. 1. will appear as *e i k f* fig. 2, and so on, till the last square which would vanish into a point, as S in fig. 2, where A S and C S meet.

6. The point S where the parallel sides of the road seem to meet is called the *point of sight*, and is still opposite to the observer, and at the height of the eye. The place where the observer's eye is placed is called the *place of the observer*, or the *point of view*. The line P S passing through the point of sight is called the *horizon*.

## CHAPTER II.

*Fig.* 1.




1. In the annexed figure it is intended to show more particularly the principles upon which this kind of perspective depends. G I K L is called the *ground plane* upon which there is a square P R S Q to be drawn in perspective; F A B C is the *plane of the picture* upon which the representation is to be made; E is the *point of view*, sometimes called the *point of sight;* it is the place of the observer's eye, and hereafter shall be called the *point of view*, and the *point of sight* shall be applied to the point opposite the eye in the horizon, to which lines and planes perpendicular to the plane of the picture converge. M N is the horizon of the picture, or the representation of the meeting of the sky and water if an observer were looking at the ocean; and it may be remarked that the horizon M N is still on a level with the eye. If a sketch were made on the top of a mountain, the horizon would then be high up; and if made from a valley or some low place, the horizon would then be low down: and in every linear perspective drawing, there must be a *horizon* or *horizontal line.* We might suppose M N was the representation of the line or visible connexion of sky and land; and this apparent meeting or line, though below the level of the eye, is still put at the eye's height, as the distance from the eye to the picture is so small, that there can be no sensible difference in taking the horizontal line M N at the height of the eye.

E D is perpendicular to the horizon M N, the point D is called the *point of sight;* the line A B in which the plane of the picture and the ground plane intersect is called the *section line:* now if lines be drawn from P Q R S to E, the points *p q r s*, where these lines intersect the plane of the picture, being joined, will form the perspective representation of the square. The operation just mentioned may be said to be of no very great use in drawing perspective, as a transparent plane cannot always be held before an object; for perspectives are made of houses, bridges, machinery, &c., before any of them are built or constructed: indeed if perspective consisted only in this, it were very contracted, and therefore of no great importance. We see, therefore, recourse must be had to other means. The point H in the ground plane, directly under the eye, is the point to which the lines are drawn from the object; we have drawn two in the diagram, as more would only have caused confusion: and from the points *a b*, where they meet the section line, we raise perpendiculars until they meet lines drawn to the point of sight in *q s*, from the points where P Q and R S meet the section line produced. If two other lines had been drawn from P R to H, and perpendiculars raised as before, they would have marked out *p r*; if then, *pr*, *q s*, &c., be joined, there would be formed *p q r s*, the perspective representation. This will be better understood by the following, with respect to the square.

2. *To put a square in perspective.* Let A B C D be the square which is to be drawn, and E the point of view. We will suppose in the first case, that the plane of the picture, or the section line *f g*, coincides with the side A B of the square, and that the point of view is exactly opposite the side A B of the square, the visual rays E D, E C, are drawn, making the side D C appear equal to H K. The side of the square is eight feet, and is laid down at the scale of an eighth of an inch to the foot. In fig. 3, *ab* is made equal to A B fig. 2, because it touches the section line or plane of the picture, and therefore it is the real size. Draw the horizontal line Y Z at the height of the eye, about five feet four inches, and as the observer stands opposite the middle of the side *a b*, the point of sight P will be also opposite the middle; join P *a*, P *b*, make *h k* equal to H K, and put half on each side of the central line, and draw the perpendicular *hd*, *kc*, and join *cd* —then *a b c d* will be the perspective representation.

3. In the second case we will suppose that the plane of the picture does not touch the side of the square, but the observer is still standing opposite the middle of the side, as in fig. 4.

Draw the visual rays E A, E D, E C, E B; then the apparent sizes of D C and A B will be H K, L M; then in fig. 5 draw the base line *no*, and at the proper height the horizontal line Y Z; leave off *h k*, *l m*, *n o*, respectively equal to H K, L M, A B, one half on each side of the central

*Fig.* 2.

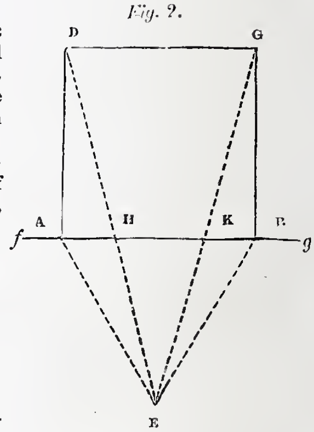



*Fig.* 3.

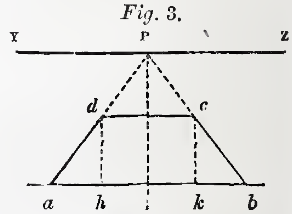



*Fig.* 4.

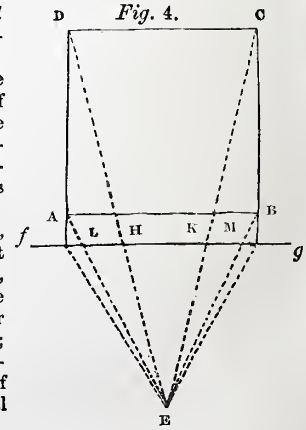
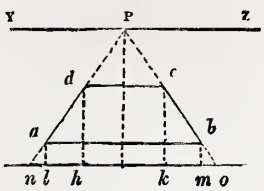


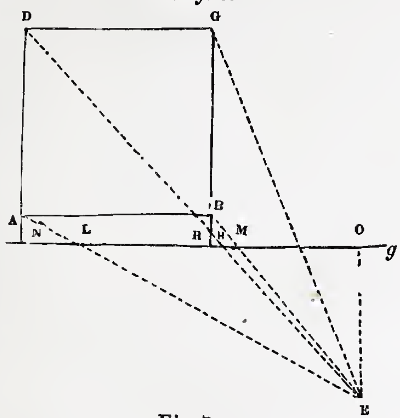
*Fig.* 5.




line; join *n* P, *o* P, and draw the perpendiculars *l a*, *h d*, *k c*, *m b*, and join *ab*, *cd*; then *abcd* will be the square.

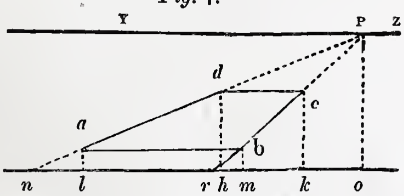
4. In the third case, we will suppose the observer stands to one side, and that the plane of the picture does not coincide with the side of the square, the plane of the picture being still parallel to the side of the square as in fig. 6.

*Fig.* 6.



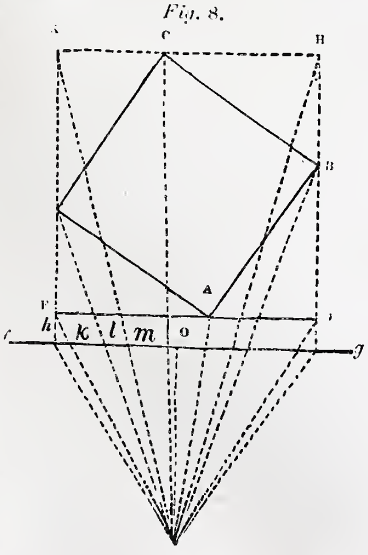

Let the visual rays be drawn as before, and let E *of* be the principal one, or the one directed to the point of sight. In fig. 7 let *n o* be the base, and Y Z the horizontal line, P the point of sight, *o* P the principal visual ray; leave off *o n*, *o l*, *o r*, &c., equal to O N, O L, O R, &c.; join *n* P, raise the perpendiculars *l a*, *h d*, &c., and join *a b*, *c d*; then *a b c d* is the square.

*Fig.* 7.



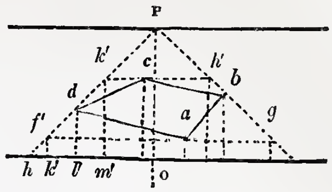

Now, the attentive reader will easily see the connexion of this method with that mentioned in description of fig. 1. The point E in figs. 2, 4, and 6, is the same as H fig. 1, which is the point perpendicularly under the eye on the ground plane. The lines though drawn from the object to it, mark out on the section line the apparent length and breadth virtually the same as if they were drawn to the point of view. Again, in fig. 1, from the points where the visual rays cut the section line, perpendiculars were raised meeting lines passing to the point of sight; the same is adopted in figs. 3, 5, and 7, where the perpendiculars are also raised, meeting lines passing to the same point.

*Fig.* 8.




In the three examples which we have given with respect to the square, and in other subsequent examples, we might have done with one figure, but we would like to impress these first principles upon the mind of the reader, in as easy a manner as possible; we have therefore adopted two figures that it may be the better understood. It is evident, that if A B C D in figs. 2, 4, and 6, had been a right angled parallelogram or rectangle, its perspective could have been as easily made; and if A B, in fig. 6, had touched the section line it would have been easier.

*Fig.* 9.




We might also mention, that if A B C D had been a pavement divided into squares, or if it were a square garden or a rectangular one with straight walks and flower plots, it could be very easily drawn by going upon the same principle which we have adopted.

5. There is still another case with respect to the square, viz:—when the section line is oblique to all of the sides, as in fig. 8.

Draw F G parallel to the section line, as also K H, and draw the perpendiculars K F, H G; draw the visual rays E F, E D, &c., and E O the principal one.

Now, let the base line and also the horizontal one be drawn, fig. 9 as before, and also *f' g' h' k'* the perspective representation of F G H K, and let *o* P correspond with E O the principal visual ray; leave off *o h'*, *o k'*, &c., equal to O *h*, O *k*, &c., and let the perpendiculars be raised till they meet the lines passing to the point of sight, &c., marking out the points *f'*, *k'*, &c., corresponding with those in fig. 8, as also *a b c d*, which points being joined, mark out the perspective representation.

We have drawn all the lines necessary on the figures, so that the student will clearly see the method of proceeding.

## THE ELECTROTYPE.

### CHAPTER II.

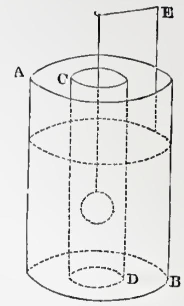
In a previous chapter, the simplest mode of copying medals, &c., by electrotype manipulation, was given. There is, however, by a different arrangement, and the application of a battery, not only a quicker process, but one by which several medals may be executed at a time, for the same expenditure of zinc as is necessary for one medal. For this purpose, a box divided with glass or porcelain, into as many cells as there are medals to be copied, the divisions being at right angles to the length of the box, is required. The wires which are fixed to the moulds are bent like the letter U, and a little copper-plate soldered parallel to them on the other end. One of these wires is suspended over each partition, placing all the moulds on the sides of the partitions next one end of the box. It will be observed from this arrangement, that each cell, with the exception of the two end ones, will have a copper-plate and a mould parallel and opposite each other, but suspended from different partitions. One of the end cells will have only a mould, and the other only a copper-plate. Into the former a copper-plate is suspended, by a wire attached to the side of the box, and to which connection is made with the copper of the battery. Into the latter, a mould is similarly suspended from the side of the box, by a wire which is connected with the zinc of the battery. A constant battery, such as Daniell's, is required for this purpose. The battery is charged in the usual way, and the box is filled with a mixture, consisting of two parts of a saturated solution of sulphate of copper, one of sulphuric acid, and eight of water. In using this apparatus, the experimenter, after having charged the battery, and filled the box with dilute acid solution of sulphate of copper, connects the wire which suspends the little copper-plate in the end cell with the copper of the battery, and then takes a wire and places one end of it into the end cell containing the copper-plate, and the other end into the other end cell containing the mould, and afterwards connects the wire which suspends the mould with the zinc of the battery. This *pro tempore* completes the connection, and in two or three minutes copper will be deposited on the mould. The end of the wire, which is into the cell containing the mould, is then taken out, and put into the adjoining cell, and the connection completed by taking one of the wires bent like the letter U, with a mould on one end and a copper-plate on the other,

and suspending it upon the partition, placing the copper-plate into the cell with the mould. In two minutes or so, this mould will also be covered with a deposit of copper. As soon as this takes place, the same end of the wire will be put into the next cell, and the connection completed by suspending another wire the same as before on the next partition, taking care to place the copper-plate in the same cell with, and opposite to, the moulds; and so on with the rest of the cells until the whole are so treated. The action is the same as in the former case, only the battery in this instance supplies the electricity. The use of the copper-plate is to keep up the strength of the solution, by being gradually converted with the sulphuric acid into sulphate of copper. In two and a half or three days, if the medals do not exceed five or six in number, and if the temperature be tolerably high, the deposit will be thick enough for removal. One cell can be used as well as any number, and the different kind of objects, copied by this method, the same as by the other plan.

Although the manipulation of copper has only been mentioned, yet all the other metals may be deposited in like manner from their different solutions. Hence has arisen the arts of electro-gilding and plating. A gold or silver surface may be obtained upon a medal, either by depositing a thin film of the metal upon it, or by covering the mould with a thin coat of the metal, and then depositing copper upon that. The metal, before being gilded or plated, must be perfectly clean. If a clean cast has been procured from a metallic mould, nothing requires to be done, but preserve it from the dust. However, if it comes from the cast soiled, or if it is taken from a stearine or wax mould, it requires a little labour to clean it, before it can be submitted to receive a gold or silver surface. This is sometimes done by rubbing it with turpentine and rotten-stone, and washing it with soap and water and a brush, and then polishing it with a piece of leather. In doing this, care must be taken not to damage the surface of the medal. It is then to be immersed among dilute nitric acid for a few seconds, and allowed to dry thoroughly, to insure perfect certainty of the metal uniting with every part of the medal. If it is not required to gild or plate the whole medal, it is only necessary to cover the parts not required with varnish. The best moulds for receiving gold or silver, and then depositing copper upon them, is *Clichee moulds*, which consist of eight parts of bismuth, five parts of lead, four parts of tin, and one of type metal. As there is a good deal to attend to in the formation of these moulds, and as they are excellent for taking *very fine* impressions of medals, we shall give Mr. Walker's directions for making them. After having mixed the different metals, by several times melting them and pouring them into drops, "a block of wood," he says, "is then turned into a shape similar to that of a button-die, into one end of which is worked a cavity, the size of the medal to be copied, and *not quite so deep* as its thickness: in this cavity the medal is placed; should it not fit tightly, a circle of paper is pressed in with it. The medal being thus firmly mounted, is to be copied in the following manner:—

"A sheet of smooth cartridge paper is fixed by drawing pins or otherwise on a flat table; the part to be used is very slightly oiled with a single drop of oil; on this is poured some of the prepared alloy, which should be removed from the fire as soon as melted. The metal is then stirred together with cards, until it assumes a pasty appearance, and is on the eve of crystallizing. If at this stage the surface should appear defaced with dross, one of the cards must be passed over it lightly and speedily: should no dross appear, this part of the process may be omitted. The die containing the medals must then be held firmly in the right hand, and be struck gently and steadily upon the solidifying metal. Should an assistant be at hand to aid in this, it will be as well; for sometimes, during the brief interim, while the card is being exchanged for the die, the exact moment is lost, and the mould is imperfect. When one stirs the metal, and the other is prepared with the die, the operation can be timed to a nicety. When an assistant is not at hand, the experimentalist should place the die within reach, at his right hand, with the medal downward."

The medals having been prepared as mentioned, the moulds consisting of the foregoing alloy may now be submitted to receive either a gold or silver surface. The simplest method for accomplishing this is, by taking a glass jar, such as A B, and placing into it a cylinder of zinc. Within the zinc cylinder a porous cell or tube C D is placed, containing the gold or silver solution. To the zinc a wire is so soldered and bent, as at E, to suspend the medal, from a thin wire to which it is attached, into the porous cell. These things having been attended to, the exciting liquid is put into the jar, and allowed to moisten through the porous cell containing the gold or silver solution. As soon as this takes place, the object to receive the deposit is suspended from the wire into the cell, and the action immediately commences. In plating, as soon as the medal is immersed, a deposit will take place, but of a dim appearance. After a second or two it is removed, and, when dry, rubbed with a little cotton, when it will present a bright appearance. It is again immersed and taken out, and treated as before, when a fine silver surface will appear. If necessary, it may be immersed in the solution a third time. Moulds that are to receive a deposit of silver ought to remain a little longer in the solution, to obtain a deposit of sufficient thickness, and then be washed with water, and afterwards with very much diluted nitric acid. The process of gilding is entirely the same as that of plating, only the former requires the object to remain a little longer in the solution than the latter. If it is required to copy objects larger than what the porous cell will admit of, a box containing a square porous vessel surrounded with zinc may be employed —the object to receive the coating of the metal being, as before, suspended from the wire to which it is attached, by a wire soldered to the zinc. A constant battery may also be employed, and a box to contain the gold or silver solution. The wire which suspends the medal in the box is attached to the zinc of the battery, and a plate of gold or silver, as the case may be, suspended near and opposite the medal by a wire connected with the copper of the battery. This process takes ten or twelve seconds before the metal can be removed. It is treated afterwards as in the foregoing case. Any objects, of whatever shape, may be either gilded or plated by either of the processes, provided its surface be a conductor.




The solution may be obtained in various ways, as may be seen from some patented processes of gilding and plating. Mr. Walker gilded and plated several medals successfully with the following preparations:—

"*Preparation for Silver Solution.*—Take one pint of pure rain or distilled water, add to it two ounces of cyanide of potassium, shake them together occasionally until the latter is entirely dissolved, and allow the liquid to become clear. Then add a quarter of an ounce of oxide of silver, which will very speedily dissolve, and after a short time a clear transparent solution will be obtained."

"*Preparation for Gold Solution.*—Warm a pint of pure rain or distilled water, and dissolve in it two ounces of cyanide of potassium as before; then add nearly a quarter of an ounce of oxide of gold. The solution will at first be yellowish, but will soon subside to white."

In the process of depositing copper upon bodies by the battery arrangement, advantage has been taken, by the consuming of the copper-plates, of producing etchings. This is very simply done by covering the plates with varnish, and after allowing it to dry, sketching through it any design; and then, as soon as the plate is placed in its proper place amongst the dilute acid solution of sulphate of copper, the acid will act upon the parts of the copper exposed, and permanently etch the subject drawn. Considerable superiority is possessed by this process over the common method of etching; but the great advantage is the application of it to daguerreotype plates.

From what has been said, perhaps an idea of the process of electrotype may be formed. To those who wish to follow the subject farther, we recommend them to Mr. Walker's work, to which we have been much indebted. A few years have only elapsed since the process was first applied to the manufacture of objects of any kind, and now many of its branches are carried on to a considerable extent in some of the manufacturing towns in the country. The advantage which the arts will ultimately derive must be very great, especially to the fine arts, to which it will give a considerable impetus. Daguerreotype plates can be manufactured at little expense, and by Professor Grove's plan for etching the design, and then producing electrotype copies, many will be put in possession, at a cheap rate, of pictures of Nature's drawing. But we must look not only to the advantages already gained by this discovery, but to those that will yet arise from it. The path discovered is wide, and while easy and pleasant to tread in, opens up to view new scenes of enterprise. In contemplating it, it tells us of the glories of science, and points to us the value of the labours of the philosopher, in speeding onward the progress of the arts. Time only is necessary to render us acquainted with its windings, to gather those pebbles with which the path is strewn. Then its advantages will become apparent, and be appreciated by all, and the discovery ever looked upon as an achievement in physical science, and an era in the arts.

# THE TELLURIUM, AN ASTRONOMICAL MACHINE.

By Edwin C. Leedom, M.D., Pennsylvania, U.S.

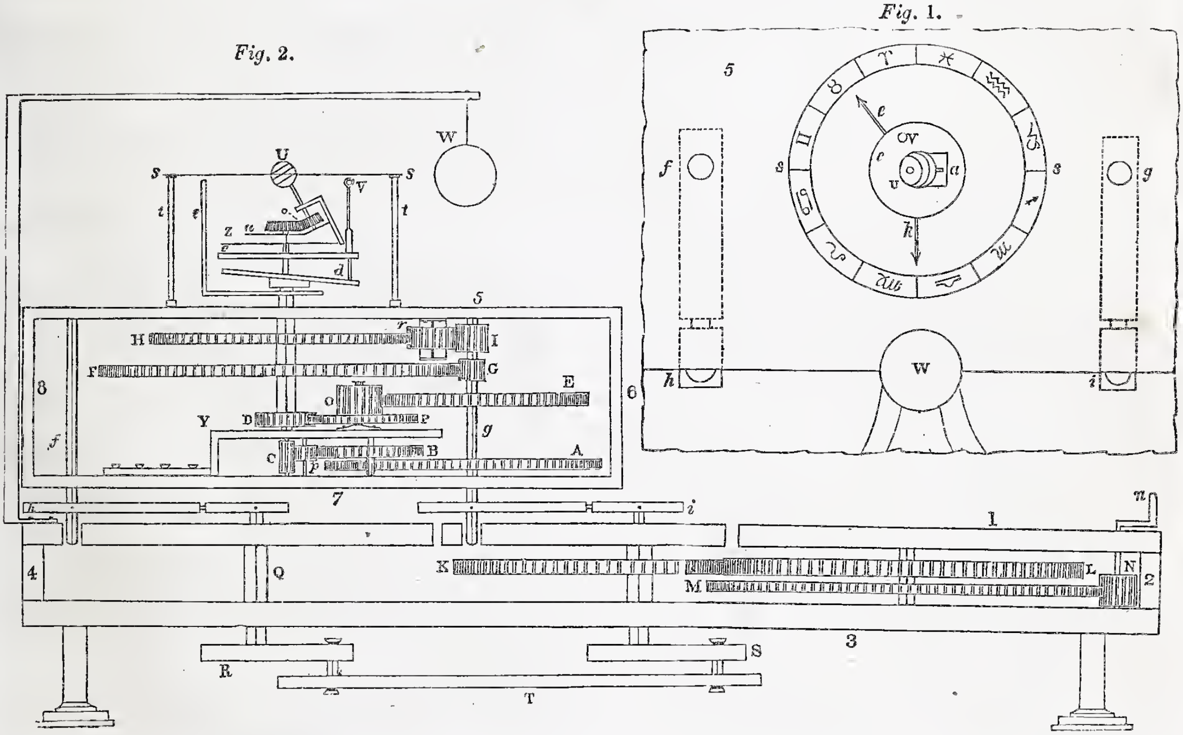
This is a machine for representing the motions of the earth and moon. The earth, whose axis has its proper obliquity to the ecliptic and keeps its parallelism, revolves round the sun in an ellipsis similar to the natural orbit, and moves with such a velocity that an imaginary line joining the centres of these two bodies, the latter being situated in one of the foci of the orbit of the former, describes equal areas in equal times. The diurnal rotations of the planet are also shown, each complete turn on its axis being made in a sidereal day, or 23h. 56m. 4s. The moon moves eastward round the earth and completes a sidereal revolution in 27d. 7h. 43m.; its nodes shift round contrary to the order of the signs, and its apogee has its direct motion eastward, the former completing a sidereal revolution in 18·6 years, and the latter in $8\frac{17}{20}$ years.

In contriving this machine I have availed myself somewhat of the inventions of other artists. To effect the unequable motion of the earth in its orbit, I have had recourse to a combination of elliptical wheels similar to that used by Dr Desaguliers in his Cometarium. There is a little Planetarium described in Ferguson's Astronomy, in which the parallelism of the earth's axis is preserved in the same manner as in this. But this machine, independently of the elliptical orbit and unequable motion of the earth, is very different from that, as will be apparent to any one who may compare them.* (See Brewster's Ed. Ferg. Astron. Vol. II. p. 6.) Although these particular parts are the inventions of preceding artists, still I think I may venture to assert, that this machine, considered as a whole, constitutes a new combination in mechanics.

In Fig. 1, this machine is represented as it would appear to an eye situated directly above it. Fig. 2 exhibits a lateral view

*Fig.* 1.

*Fig.* 2.




of the wheelwork. In either fig. the ball W, represents the sun, the ball U the earth, and V the moon; $k$ is an index for showing the place of the moon's ascending node, $e$ is another index for showing the place of its apogee, and $n$ is a winch by which the machinery is moved. The earth is surrounded by a little brass ring $s$, which is set upon four pillars $t$ $t$, and has the signs of the zodiac marked upon it. Upon this ring, which moves with the earth and keeps its parallelism, the geocentric places of the sun, moon, its ascending node and apogee, can be seen. 1 2 3 4, Fig. 2, is a wooden frame, in the top of which are two equal elliptical grooves, similar to the earth's orbit, and which have their foci all situated in one straight line. Within the frame are two elliptical wheels, K and L, which are of the same size and eccentricity as these grooves, each wheel having its axis situated in one of its foci. The axis of the wheel L also carries a large circular wheel M; next to which is placed a pinion N, upon the upper end of whose axis the winch $n$ is fixed. Q is a stout metallic axis of the same size as that which carries the wheel K. These two axes pass perpendicularly through the boards 1 and 3, the upper part of each axis where it comes through the board 1 being situated in one of the foci of one of the elliptical grooves. Upon the upper ends of these axes two arms $h$ and $i$ are tightly fixed. Two other arms R and S are fixed upon their lower ends so as to be perpendicular to $h$ and $i$. T is a narrow metallic plate, which is connected with the arms R and S by two moveable joints: this plate assists in regulating the motion of the machine. Into the arms $h$ and $i$, are inserted two axes $f$ and $g$, which pass up through a moveable frame 5 6 7 8, and turn freely within it. The lower end of these axes project into the elliptical grooves in the board 1, and slide along these grooves when the machine is in motion,—the arms $h$ and $i$ being so contrived, as either to lengthen or shorten according as the distance of the groove from its focus increases or diminishes.

* When I made the first machine of this kind, and for several years after, I believed myself to be the original inventor of this mode of preserving the parallelism of the earth's axis, but I was at length undeceived by a perusal of Ferguson's book.

The moveable frame 5 6 7 8 contains a number of wheels, which serve to rotate the earth on its axis, and give motion to the moon, its nodes, and apogee. A metallic supporter Y has inserted into it a long and narrow socket, which passes up through a hole in the plate Z. Upon the upper end of this socket a small brass arm *a* is fixed, which holds a pinion *o*, whose axis forms an angle of $23\frac{1}{2}$ degrees with the perpendicular, and carries the earth U. C is a pinion whose axis passes up through this socket, and is surmounted by a very small wheel whose teeth act upon the leaves of the pinion *o*. D, F, and H, are three wheels, each of which is fixed upon a separate socket. The socket of the wheel D turns upon the socket which is fastened into the supporter Y. The socket of F turns upon the socket of D; and the socket of H turns upon that of the wheel F. Upon the upper end of the socket of D a small circular brass plate *c*, is fixed, into which, near its edge, is inserted a small flattened socket, through which passes a flattened wire which carries the moon V. The lower end of this wire rests on another circular plate *d*, which is fixed upon the socket of the wheel F, and has an oblique position, forming an angle of $5\frac{1}{2}$ degrees with a horizontal plane passing through its centre. This wire is kept constantly applied to the plate *d* by means of its own gravity, and slides along this plate as *c* turns round, the wire alternately rising and falling in its socket; consequently, the orbit in which the moon V moves must always be parallel to the plate *d*, and form an angle of $5\frac{1}{2}$ degrees with the plane of the ecliptic. The index *e*, which points to the moon's apogee, is fixed upon the socket of the wheel H. The axis *g* carries four wheels, A, E, G, and I, which all turn as one wheel. Next to the wheel A is placed the pinion of a wheel B, whose teeth act upon the teeth of a small wheel *p*, which transmits motion to the pinion C. The teeth of the wheel E act upon the teeth of the wheel O, whose axis also carries a wheel P, which gives motion to the wheel D. The teeth of the wheel G act upon the teeth of the wheel F; and lastly, motion is transmitted from the wheel I to the wheel H by means of an intervening wheel *r*.

When the winch *n* is turned by a steady hand, the leaves of the pinion N act upon the teeth of the large circular wheel M, and turn it and the elliptical L on their common axis with an equable motion. The teeth of L at the same time act upon those of the wheel K. As K turns, the arms *h* and *i* both move in the same direction, and carry the moveable frame 5 6 7 8 parallel to itself, over and over the top of the large stationary frame 1 2 3 4. The earth U is carried along with the moving frame, and has the parallelism of its axis also rigidly preserved. As the ends of the axes *f* and *g* slide round in the elliptical grooves, in the board 1, it is apparent that the orbit described by the earth U must be an ellipsis of the same size and eccentricity as either of these grooves. When the earth is in its perihelion, as represented in the drawing, (Fig. 2,) that part of the circumference of the elliptical wheel L, which is farthest from its axis, and has the greatest velocity, is applied to a part of the circumference of K which is nearest to the axis of the latter wheel, consequently the earth must have its quickest motion. When the earth comes to its aphelion, these elliptical wheels have a reverse position with respect to each other, which gives the earth its slowest motion. These elliptical wheels working together in this manner, give the earth U the same unequable motion in its orbit, that the real earth has in nature.

The wheels, A, E, G, and I, all make one complete turn on their common axis *g* during an entire revolution of the earth round the sun. The wheel A contains 293 teeth, and the pinion which belongs to the wheel B contains 8 leaves, consequently B must make $36\frac{5}{8}$ turns during one turn of the wheel A. The wheel B contains 80 teeth, and the pinion C contains 8 leaves; consequently C must make ten turns during one turn of the wheel B, and ten times $36\frac{5}{8}$ or $366\frac{1}{4}$ turns during one revolution of the wheel A, that is, in one year. The little wheel upon the upper end of the axis of the pinion C contains the same number of teeth as the pinion *o*, therefore the earth must turn on its axis in the same time as the pinion C; it must make $366\frac{1}{4}$ diurnal rotations in a year, each rotation being performed in a sidereal day, or 23h. 56m. 4s. The wheel E contains 167 teeth, and the wheel O contains 25 teeth. Consequently O, and also the wheel P, must make $6\frac{17}{25}$ turns during one turn of E. The wheel P contains 72 teeth, and the wheel D contains 36 teeth, consequently D must make two turns during one turn of P, and twice $6\frac{17}{25}$ or $13\frac{9}{25}$ turns during one turn of the wheel E, or in one year. As the circular brass plate *c* is fixed upon the socket of the wheel D, this plate must turn with the wheel and carry the moon V $13\frac{9}{25}$ times round the earth U in a year, which is equal to the number of the moon's sidereal revolutions in this time. The teeth of the wheel G act upon the teeth of the wheel F. The wheel O contains 20 teeth, and the wheel F contains 372 teeth, consquently G must make $18\frac{6}{10}$ turns, while F turns once round. As the wheel G makes but one turn on its axis in a year, the wheel F must require $18\frac{6}{10}$ years to perform a revolution. The oblique plate *d*, to which the moon's orbit is parallel, being fixed upon the socket of the wheel F, the plate must turn with this wheel and carry the moon's nodes round contrary to the order of the signs, so as to perform a sidereal revolution in $18\frac{6}{10}$ years. The teeth of the wheel I act upon the teeth of the wheel *r*, which, as before stated, transmits motion to the wheel H. The wheel I contains 20 teeth, and the wheel H contains 177 teeth, consequently I must make $8\frac{17}{20}$ turns in order to turn F round once. As the wheel I makes only one turn in a year, the wheel H must be $8\frac{17}{20}$ years in performing a revolution. The index *e*, which is fixed upon the socket of H, must turn with this wheel and also perform a revolution in $8\frac{17}{20}$ years, which is the time in which the moon's apogee performs a sidereal revolution; therefore, this index will show the proper motion of the apogee.

This machine being rectified by the astronomical tables for any particular time, if the winch *n* be then turned from right to left, the machine will exhibit the vicissitudes of day and night, variety of seasons, new and full moons, eclipses, anomalies of the sun and moon, or year after year.

As the earth has the same unequable motion in its elliptical orbit that the real earth has, this machine will show the sun's true place correctly for a great length of time.

*A Table showing the dimensions of the wheels of the Tellurium, number of teeth, &c.*

Wheel A, 293 teeth, 12 teeth in an inch of circum. Diam. 7·77 inches.
Wheel B, 80 teeth, 8 teeth in an inch of circum. Diam. 3·18 inches.
Pinion of wheel B, 8 leaves. Diam. 21-100ths of an inch.
Wheel *p*, 24 teeth, 8 teeth in an inch. Diam. 95-100ths of an inch.
Pinion C, 8 leaves. Diam. 31-100ths of an inch.
Wheel E, 167 teeth, 8 teeth in an inch of circum. Diam. 6·64 inches.
Wheel O, 25 teeth, 8 teeth in an inch. Diam. 99-100ths of an inch.
Wheel P, 72 teeth, 8 teeth in an inch. Diam. 2·86 inches.
Wheel D, 36 teeth, 8 teeth in an inch. Diam. 1·43 inches.
Wheel G, 20 teeth, 12 teeth in an inch of circum. Diam. 53-100ths of an inch.
Wheel F, 372 teeth, 12 teeth in an inch. Diam. 9·86 inches.
Wheel I, 20 teeth, 8 teeth in an inch of circum. Diam 79-100ths of an inch.
Wheel H, 177 teeth, 8 teeth in an inch. Diam. 7·04 inches.
Wheel *r*, 40 teeth, 8 teeth in an inch. Diam. 1·59 inches.
Elliptical wheels K and L. The longer diameter of each wheel, 10 inches. Distance between the two foci 17-100ths of an inch. Both of these wheels contain the same number of teeth.
Wheel M, 280 teeth, 8 teeth in an inch. Diam. 11·14 inches.
Pinion N, 16 leaves.
Elliptical grooves in the board 1. The longer diameter of each groove, measuring from the middle of the groove on one side, to the middle of the groove on the opposite side, 10 inches. Distance between the two foci 17-100ths of an inch.—*Silliman's Journal.*

## CORROSION OF IRON IN STEAM-BOILERS AND STOVE-PIPES,

### IN WHICH ANTHRACITE IS USED.

REPORT of the Committee on Science and the Arts, constituted by the Franklin Institute of the state of Pennsylvania, for the Promotion of the Mechanic Arts, to whom was referred, for examination, the Corrosion of Iron in Steam-boilers and Stove-pipes, where Anthracite is employed as fuel:—

THE Committee have gathered such information as lay in their power from those who have witnessed the corrosive action, and combined it with their own observations.

It appears that stove-pipes are frequently corroded in the course of a year, or two, were they are not taken down or cleansed subsequent to their employment through the winter

season. An instance is known in which forty feet of pipe were corroded and rendered a perfect colander in the course of two years. Nor does it appear always as a necessary condition that the place should be damp, although this is the case in a majority of instances; for, in the corrosion just noticed, the proprietor stated that the stove was very dry. The corrosion rarely happens in an upright pipe, but usually in one lying horizontally; for, where such corrosion had already commenced, it was said, in one instance, to have been obviated by giving the pipe a slight inclination. Where it takes place in an upright pipe, it may arise from the flowing down of corroding matter from a horizontal layer of the same.

The same kind of corrosion is observable in steam-boilers in which anthracite is employed as fuel, and not in those in which bituminous coal is used. That it does not arise from the intensity of the heat is shown from the fact, that it is greatest in the boiler-flues which lie horizontally at a distance from the fire. A corrosion is sometimes observed near the top of the smoke-pipe in steam-boats, but this may be attributed to the alternate action of heat, cold, air, and moisture.

It would appear, then, that the corrosion is caused either by the vapours arising from the combustion of anthracite, or from matter carried up mechanically by the draft, or from both combined. That it does not proceed from uncondensable gaseous matter is proved by the occurrence of the corrosion, only when a stove-pipe is no longer exposed to these vapours during the summer season, or where a boiler is cooled from intermitted fires. It does not arise from matter carried up mechanically; for this could only be ashes;—and we know that the ashes of anthracite are of a dry nature—and without moisture, chemical action, or the corrosion, could not occur. It must, therefore, be produced from condensable vapours.

On examining the interior of a stove-pipe lying horizontally, whether corroded or not, we find a loose ashy deposit of a greyish brown colour; and where corrosion has taken place, the greater part is condensed into a solid mass, showing that it had absorbed water. Upon fracturing the solid material, small white crystals appear under the microscope, which are generally too imperfect to admit of recognising their form. By subliming the mass, a little empyreumatic oil and water are formed; but the greater part sublimed is an ammoniacal salt. Upon testing a solution of the ashes, it shows a large content of muriate and sulphate of ammonia—the former evidently in much greater quantity than the sulphate. After complete sublimation at a red heat, the ashy matter remaining appears to be nearly pure charcoal or lampblack, with a mere trace of coal-ashes. From the qualitative tests made, it would appear that the ammoniacal salts constitute at least three-fourths of the whole mass. A mere trace of iron was detected.

From this content of saline matter, as well as from its nature, we are at no loss to account for the corrosion of iron where the air and moisture add their conjoint action; but it may be doubted whether the ashy matter has the power of absorbing moisture from an atmosphere of ordinary dryness; for in dry situations, it appears that there is usually no corrosion, and in the case noticed at the commencement of the report, it may be doubted whether the stove was dry.

How to obviate the corrosive action is a more difficult point to determine, unless the very simple process be resorted to, of cleaning out stove-pipes every spring, and boiler-flues every few weeks. If the stove-pipes are required to remain standing with the sediment in them, then a previous internal coating of white lead, litharge, or red lead, might probably answer the best purpose, since it would result in the production of chloride and sulphate of lead, while the ammonia would be driven off. The thin coating of these salts of lead might then prevent the contact and further action of the ashy deposit. Experiments made at the U. S. Mint, during the winter of 1840–41, seem to show that a coating of lime on the interior of a pipe prevents corrosion, and it is said that a few stove manufacturers in this city are acquainted with the fact. The committee, however, in the face of these facts, are rather inclined to believe that the oxide of lead will prove more efficient, since the sulphate of lead is a wholly inert salt, and the chloride nearly insoluble; while the sulphate of lime is somewhat soluble, and the chloride of calcium very soluble, and therefore likely to produce corrosive action eventually. Still the operation of whitewashing is the simplest mode of obviating corrosion, and may be repeated at intervals.

The content of chlorine, to such an extent as is developed by the above chemical examination, is interesting in a geological point of view, since it has not hitherto been found in chemical examinations of anthracite. Professor H. D. Rogers, in 1836, pointed out the fact, that where heaps of refuse matter were burned near the coal-mines, ammoniacal salts, and among them muriate of ammonia, are sublimed, and may be found among the ashes. Now we know that the saline waters are obtained from the coal measures in the western district of Pennsylvania; and moreover, it is the prevailing opinion among geologists, that the coal series are marine deposits; we can, therefore, explain the origin of the muriate of ammonia in the ashy deposit, arising from the combustion of anthracite, by attributing the chlorine to the presence of a trace of chlorine of sodium (common salt) in the coal or its accompanying slate, or possibly in both. It is unnecessary to allude to the formation of ammonia, since it is a universal product, to a greater or less extent, of the dry distillation or combustion of every kind of coal.

This ammoniacal deposit is interesting in an economical point of view, since it accumulates in considerable quantity in a single season, and may be collected with facility. In one instance, at least, ten pounds were removed from about eight to ten feet of pipe, which was the produce of three or four years, and hence we may estimate the large amount that might be obtained from many hundred pipes in Philadelphia every season. It may be employed either for the manufacture of sal-ammoniac, by a very simple process of sublimation with a small quantity of a salt of lime, or it may be directly applied in powder, or in solution, to garden soils. The influence of ammoniacal salts in promoting luxuriant vegetation has long been known; but the admirable work of Professor Liebig on Agricultural Chemistry, has more completely developed their influence and importance. The material before us will, unquestionably, prove of great value to the gardener and florist, if properly applied to the soil; but it must not be forgotten that it is very rich in ammonia, and should therefore be employed sparingly.

By order of the Committee,

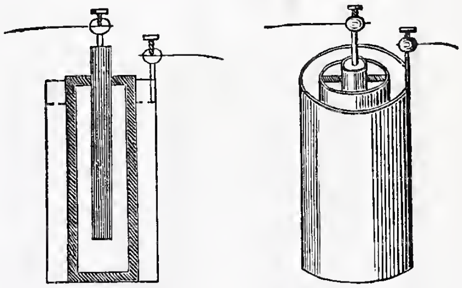
William Hamilton, *Actuary.*

## GALVANIC BATTERIES.

### CHAPTER II.

The constant battery of Professor Daniell, shown in section and elevation, consists of an exterior or outer vessel of cop-

*Fig.* 1.



per, inside of which is placed a cylinder of porous earthenware, closed at the bottom. Unglazed jelly-pots answer extremely well for the porous vessel, and may be had at any pottery. Within the porous cylinder is suspended a cylindrical rod of zinc, resting upon the top of the porous cylinder by a piece of wood put through the zinc rod. Binding screws are attached to the copper cylinder and zinc rod, which completes the construction of one cell. Any number of cells can be arranged so as to form a battery of considerable power; and by having binding screws, in place of cups filled with mercury, any number of cells can be thrown out of action with greater facility; or the whole battery can be arranged as a single pair. To put a battery of this construction in operation, the space between the copper cylinder and porous tube is to be filled with a saturated solution of sulphate of copper; and the interior of the porous tube, in which the zinc is placed, may be filled either with dilute sulphuric acid, or a solution of common salt. When the battery is required to be kept in action for any considerable length of time, a few crystals of sulphate of copper must be placed on the annular ring of copper—which ring is pierced with holes to allow the fluid to have free access to the crystals placed upon it—so that they may be

dissolved slowly, just as the copper held in solution gets deposited upon the inner surface of the copper cylinder. Amalgamating of the zinc rods is attended with considerable benefit, especially if the action is to be long continued, by preventing local action, and the deposition of oxide of copper upon the rods. A very economical arrangement of a battery, upon this principle, may be made by substituting earthenware vessels in place of the outer vessels of copper, by coating the interior of them with a thin covering of wax, and then depositing a coating of copper on their inner surface by the electrotype process, as follows :—The earthenware vessels being coated with wax in the interior, they are then to be well brushed with black lead, until the whole surface of the wax is of a dark black colour ; the vessels are then to be filled with a saturatod solution of the sulphate of copper,—a porous vessel containing a little acidulated water being placed in the solution ; also, a piece of zinc, with a stout copper wire attached, is to be placed in the porous vessel,—the other end of the wire being placed in contact with the black lead on the surface of the wax. A simple current is thus brought into action, and in a few hours a coating of metallic copper will be found adhering to the whole of the inner surface of the earthen vessel, thus forming a complete cylinder of copper, which increases in thickness by the deposition of copper whenever the battery is in action.

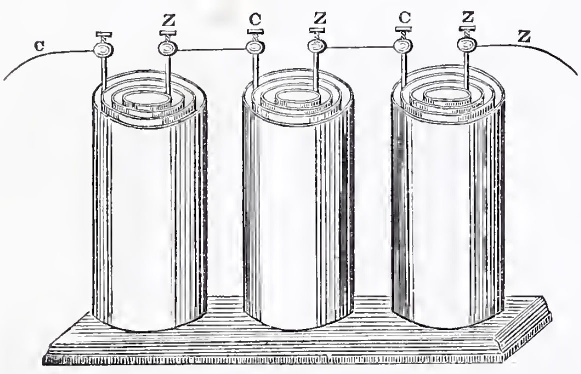
The advantages gained by using this form of battery, over that of the common acid battery, are, steadiness of action when used for a considerable length of time ; for, by simply keeping a few crystals of sulphate of copper suspended in the solution, its action will remain perfectly constant for days, and even weeks, if required.

No annoyance from the evolution of gas is felt as in the common battery, an advantage of no small moment to those engaged in studying the principles of voltaic electricity.

Grove's battery is constructed upon the same principle as Daniell's, differing only in the arrangement of the metals, and in the substance used to excite it. It may be constructed as a series of jars, or in the common trough form, with divisions of glass or earthenware. The pot form is much cheaper and more easily arranged than the other.

To construct one of the pot form, (say of 6 cells, fig. 2,) take

*Fig. 2.*

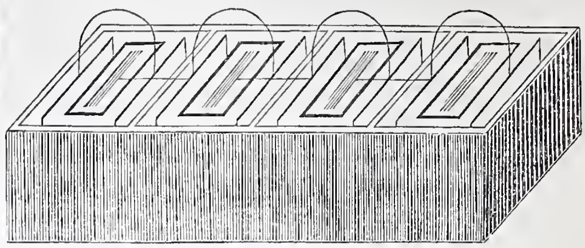



6 jelly-pots of a convenient size, and as many porous tubes. So far the arrangements are the same as Daniell's ; the metals, however, are differently placed. In the outer space is placed a cylinder of rolled zinc, and within the porous tube a plate of platinum ; the space containing the zinc is to be filled with a dilute solution of muriatic acid, or the porous tube with the strongest nitric acid. The action of the battery, when first excited, is very energetic to its size.

For electro-magnetic purposes it is peculiarly applicable, occupying very little space in proportion to the amount of effect produced, besides diminishing the weight, which has all along been an impediment in the way to those who have turned their attention to construct locomotive machines propelled by electro-magnetic action. This form of battery does not continue for any great length of time in constant action ; its energy gradually declines, owing to the volatilizing of the nitric acid, and is very disagreeable to work, especially in a close room,—the fumes of the strong nitric acid being of a very pungent nature.

Fig. 3 represents another form of Grove's battery, viz., the

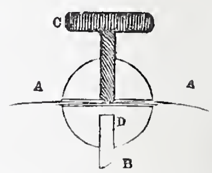
*Fig. 3.*



common trough form. The trough may be made either of wood, perfectly dry, and covered with a coating of strong spirit varnish : the divisions may be made of wood, glass, or earthenware, perfectly water tight, so that either one or more of the cells can be dispensed with, according to the wished-for effect. The great quantity of nitric acid necessary to excite a battery of the pot form is here got quit of—for the porous vessels need not be above $\frac{8}{10}$ of an inch wide—consequently requiring little acid to fill them, and the outer space or division of the trough may be filled with a solution of common salt, in place of dilute muriatic acid.

For the purpose of connecting the plates of the battery, it is much more convenient to attach to each plate a stout wire or strip of metal, to the end of which is soldered a binding screw. Fig. 4 represents a section of a connecting apparatus. D is a small ball of brass into which is soldered or screwed the end of the wire B, attached to the plate of the battery ; C a milled headed screw for pressing together the two wires A A for connecting the different plates of the battery together, by which means the battery can be very easily arranged either in series, or the whole connected as a single pair.

*Fig. 4.*




Smee's battery consists of zinc and platinized silver plates, two of the latter and one zinc plate being placed in a jelly-pot and excited with dilute sulphuric acid. The advantages to be derived from this arrangement, as stated by Mr Smee, are, the freedom with which the hydrogen is liberated from the rough surface of platinized silver, in comparison with the slow disengagement from a plane plate of metal, which is sometimes caused by a thin film of air interposing between the plate and the acid ; to prevent which it is necessary to separate the metals to a much greater distance, thereby weakening the energy of the battery, in causing the fluid to traverse a greater distance of the exciting liquid,—it being well-known that the power of a battery rapidly decreases as the plates are kept farther separate. According to Professor Ritchie, the decrease is inversely as the square roots of the distance of the plates. Mr Grove, of the London Institution, has suggested a further improvement upon the platinized plates, which is to use silver wire gauze in place of silver plates for depositing the platinum upon, in which case the plates may be brought nearly close together, the liberated hydrogen making its escape through the meshes of the wire gauze, and passing up the outside. In substituting the wire gauze in place of the plane plates, great care will be required to get every part of the wire gauze covered with the deposition of platinum ; for if any part of the wire is exposed, a local action will take place between the silver and platinum, which greatly impairs the action of the battery. In using a battery of this construction for a series of experiments requiring a considerable length of time for their accomplishment, and where it is requisite that the battery be kept at a uniform rate, it is better to employ porous vessels, so that the sulphate of zinc may be kept from getting diffused amongst the acid in which the platinized plates are placed : this arrangement will separate the plates to a greater distance than the former, thus weakening the energy of the battery ; but the more uniform rate of action obtained by the latter arrangement will compensate for the decrease. By add-

# EDMONDSON'S RAILWAY TICKET DATING PRESS

*Fig 1*

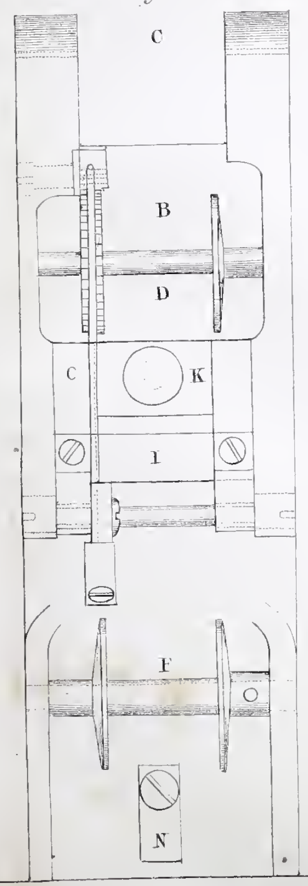



*Fig 2*

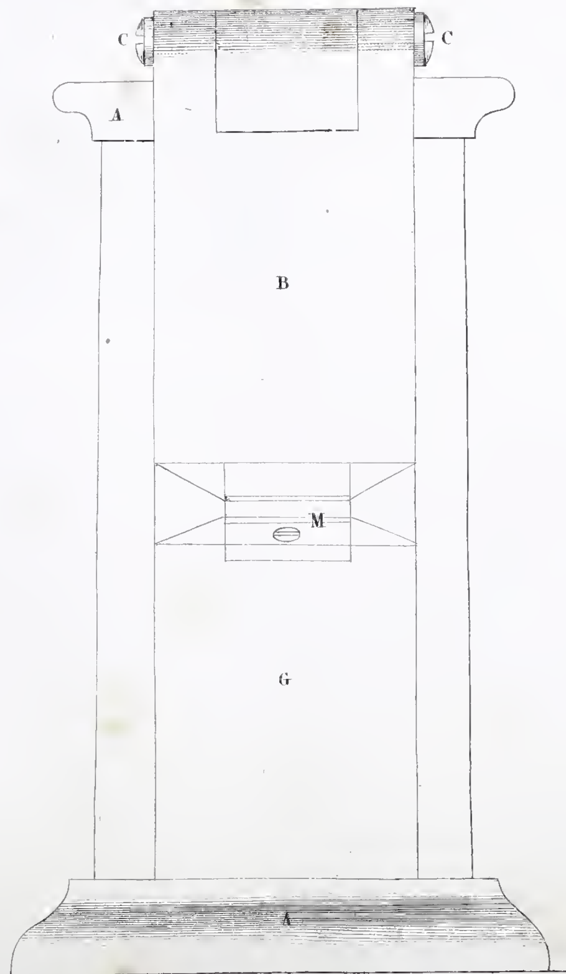
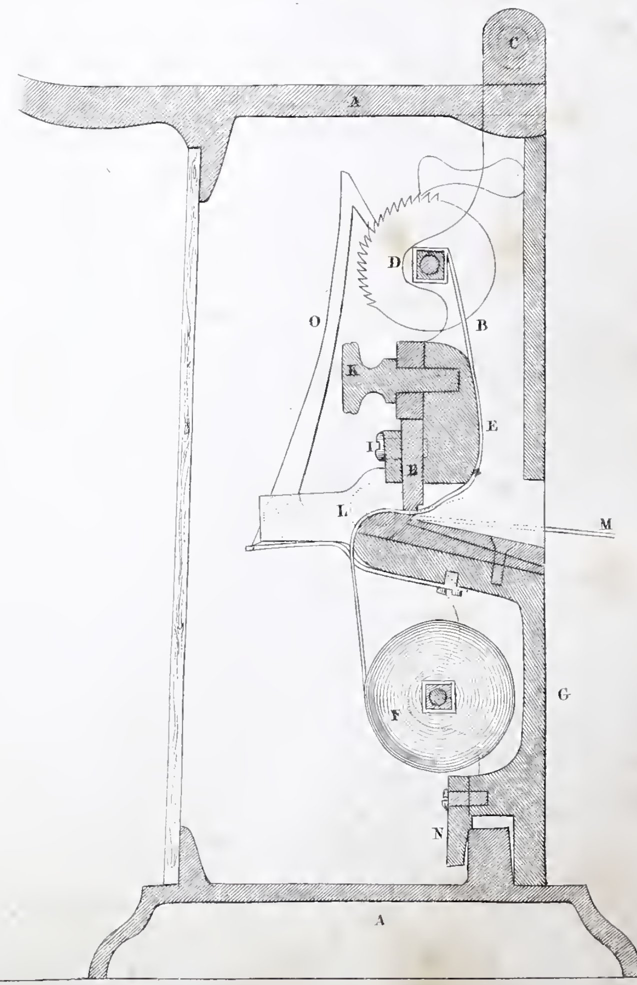



*Fig 3*




*Scale_Half Size.*

ing one or more cells to the battery, its power or energy may be made to equal that of the undivided arrangement.

A battery wholly composed of one metal, and fitted up on the principle of Grove's, with porous diaphragms, has been tried by M. Wohler, and an account of it has been published in the *Pharmaceutical Journal*. The metal used is iron; the solution strong nitric acid, and dilute sulphuric acid. The plate or cylinder that is used for the inner or porous vessel must be well polished, in which case the nitric acid has no effect upon it; the outer plate or cylinder which is immersed in the sulphuric acid does not require to be polished, as it stands in the place of the zinc in the common battery, or forms the positive pole,—the iron being gradually dissolved when the battery is in action.

The effects produced by this form of battery are very energetic when first excited; but it rapidly declines in effect, from the weakening of the nitric acid. The dense red fumes given off, are, moreover, very disagreeable and highly deleterious. It is also very expensive to work, owing to the high price of the nitric acid, as it is essential that the strongest be used.

## RAILWAY TICKET PRINTING MACHINERY.

*Illustrated by three Plates.*

In the early days of any vast and sweeping improvements, we invariably find its promoters too much occupied in putting their general details into regular operation, to pay attention to the minute, though necessary points connected with the successful management of their venture. In how few cases do we discover any elegancies of manufacture, until years after the primary application of the principle. The railway system affords perhaps the best example of what we may term a rapidity of organization. It is true that a long period has elapsed since its first introduction; but since the fostering hand of the capitalist has been extended to it, how speedily has it extended its ramifications, and become part and parcel of our every day wants. As an illustration of the perfection of many of the minor details of this stupendous agent, we would refer the reader to the complicated and ingenious machinery invented by Mr Edmondson, for the simple operation of facilitating the printing and distribution of the fare tickets. So extraordinary is the demand for these passports, that, on most of our extensive lines, the ordinary manual operations formerly connected with their issue were found quite inadequate to the due management of this portion of their commercial details. Mr Edmondson, who has been long connected with railway matters, foresaw the difficulty, and as a remedy, has provided us with the machinery represented in the plates accompanying this article, for printing and numbering the tickets. Fig. 1 is a side elevation of the machine. Fig. 2 is a front view, and fig. 3 is a longitudinal section through the centre, showing the internal details. The whole of these figures are accurately drawn to a scale of one-third the original size. The frame work A A, is composed of two cast iron standards, bolted to a bottom plate, not shown in the view; this frame carries suitable supports for the attaching of the blank ticket case B. The tickets to be printed, are put in at the top of the case, which is surmounted by an ornamental cover; they are drawn away from the bottom, as shown at C. In order to understand how this is accomplished, we must refer the reader to the lever apparatus, worked by the handle D. This lever or handle works on a centre at E, attached to the standards of the frame, and carries the jointed printing table, being attached to the pendant lever of the table F. One end of the table, G, is used for imprinting the ordinary matter referring to regulations, &c., usually found on the tickets; the other extremity H, is employed solely for numbering. The types for imprinting the tabular matter are placed in the fixed box I, which is adjustable, by means of the hand screw G, immediately above it. A cloth band, K K, well soaked in thick printing ink, is wound upon the roller, L, from whence it is passed round various guides, and runs beneath the case of types, I, being re-wound upon the roller, M. Each ticket is brought separately from the bottom of the case, B, by means of a sliding plate attached to the top of the vibrating lever, N, worked from the handle, D; this plate is recessed on its upper surface to the depth and size of a single ticket, so that at each vibration, it receives the lowest ticket from the series in the case, and transfers it to that portion of the table immediately beneath the types. By referring to the connections of the lever, D, it will be observed that each upward movement carries forward the ticket by means of the lever, N, whilst each downward one raises the impressing table, and forces it against that portion of the inked ribband or band, which is beneath the types, I. In this way the prominent portions, that is, the faces of the types only, are impressed upon the tickets *through* the ribband, thus imprinting upon it whatever matter may be set in the type box. The ribband, which is well soaked in ink previous to being put on the machine, affords a means of keeping up a constant supply of ink, in the most ingenious manner; after each impression, a new portion is presented to the types, being worked onwards by means of the ratchet rod, O, which is jointed to the motive lever, D. This rod carries a series of detents, connected with the ratchet wheels on the roller shafts L and M, so as wind up from the one, the same amount of ribband that it gives off from the other—the same rod also carries a detent gearing with a large ratchet wheel on the numbering wheel shafts P, which are moved the distance of a single number at each impression of the tickets. The last ticket detached from the case, pushes its predecessors before it, so that there are always several tickets in contact with each other on the table G H, the last one being pushed forward by those behind, at each stroke, and when numbered, drops into the box Q, at the front of the machine. The numbering wheels P, are arranged to number to 10,000, the first wheel carrying the figures 1 to 99, and the second from 01 to 00; at each whole revolution, one of the two is carried forward a division before the other, by an arrangement of pins, seen in fig. 2, in order to effect the requisite change at each 100. In fig. 2, the *finished* ticket case Q, is shown full of tickets, as they are thrown in from the table—there is an arrangement provided for conveying them straight down the tubular case, which is not shown in the drawing, in order to avoid confusion. This is a sliding spring block, similar to that shown in Plate 3rd, which is adjusted to support each ticket as it falls into the tube, preventing its turning over or getting into any position out of the horizontal.

After the process of printing and numbering, the tickets are transferred to a series of cases, each numbered to represent the particular station for which the tickets are intended, whence they are selected for distribution.

Plate 2nd represents the press used for dating the tickets, previous to their delivery to the passengers. Fig. 1 is a section through the centre of the machine; fig. 2 is a front view, showing the opening by which the ticket is introduced, and fig. 3 is a back elevation of the machinery detached from the external case. A, A, is the outer case of the machine, to the top of which, the type holder B, is jointed at C. D, is the roller upon which the inking ribband E, is coiled during the act of dating, being drawn upwards beneath the types, from the roller F, which works loosely in bearings in the lower portion of the impresser G. The types are seen at H; they are held in their exact position by means of the cross piece secured by the screw I, the whole being removeable by unscrewing the screw K; the two portions of the impressers B and G are jointed together, as seen at L, so that when the ticket M, is introduced into the opening in front of the machinery, and pres-

sure applied upon the part marked , the whole acts as a knee joint, and brings the types to bear upon the ribband, and through that, upon the ticket, as explained with reference to Plate 1st. The lower portion, N, of the piece G, is arranged to slide upon a fixed piece on the bottom plate of the machine, in order to permit of the proper action of the joint L. By this simple apparatus, the tickets are quickly dated in the order in which they may be required for the traffic of the lines. In order to simplify the checking and counting of the tickets issued to the different heads of the railway departments, Mr Edmondson has introduced the Counting Machine, represented in Plate 3rd. The drawings are here of the full size of the machines actually in use. Fig. 1 is a side elevation of the machine, showing the toothed gearing used to increase the speed of counting. Fig. 2 is an end view. *a, a,* is the case containing the tickets to be counted off, a few being shown by the dotted lines near the bottom; they are each detached one by one, from the case, by the slide *b*, which is worked by the crank, connecting-rod, and lever *c d f*: they are received into the tube *l*, on the top of the spring block, which must be moved gently down by the left hand as they are driven in. This tube is kept in its place by the small spring-catch on the tube. This is not shown in fig. 2, to prevent confusion; at each turn of the crank, the eccentric *g*, which is keyed fast upon it, gives motion to the ratchet-wheel *h*, by means of the bell crank and click *i k*; the ratchet wheels have each a hundred teeth, and likewise a brass ring fixed to each, divided into a like number of divisions; the unit wheel ring is numbered 01 up to 99 and 00, the hundred wheel is numbered 1 to 99, the other space remaining blank, which is at the sight, *o*, in the plate, *p*. At covering part of the wheels; the wheel *h* or unit wheel is supposed to have made one revolution, except the 100th, to show which the 100th wheel must be brought into action; this is done by the small detent that is fixed upon the unit wheel, and as it moves forward to the division with 00 upon it, the detent acting upon the bell crank and click, *r s*, moves the 100th wheel forward one division, which will show 160 at the sight *o*; the click *s*, when released will take its original position, so that it may be worked on without taking any further notice until the highest 9999 is arrived at. The wheel and pinion arrangement is merely for the purpose of increasing the speed of the machine; by causing the handle to revolve 170 times per minute, 500 tickets may be driven out in the same manner.

## DOMESTIC MEDICINE.

### CHAPTER III.

#### ON THE PHYSICAL CAUSES OF DISEASE.

In last chapter we drew attention to the powerful influence which *moral causes* have in the production of disease. We attempted to show that selfish and worldly motives alone, independent of religion, ought to induce us sedulously to avoid these causes; and that, in proportion to the intensity of our religious feeling, our conscience—that inward monitor—will the more effectually warn us to shun those slight deviations from the path of rectitude, that will lead us imperceptibly to the brink of the precipice of depravity, and will finally hurl us headlong into the gulfs of moral degradation, disease, and premature death.

The attention of the reader will now be directed to the influence of *physical causes* in originating and promoting disease; and as we may see that civilization tends to lessen the moral causes of disease, only in so far as it is based on religion, so will we see that its influence in diminishing the physical causes consists in its promoting a discovery of these causes; and as it is the duty of the clergyman to instil pure religious feelings into society, so is it the duty of the physician to promulgate a knowledge of the physical causes of disease among all classes of the community, thus fulfilling the noble aim and end of his profession—*to lessen the amount of human misery.*

The diseases which chiefly occur among *savage* nations are few and simple: fevers, fluxes, and rheumatisms may be said to complete the list. They arise mainly from exposure to vicissitudes of temperature.

Travellers are forcibly struck with the healthy appearance, the finely-shaped and athletic figures, and the power of endurance of hunger and fatigue, exhibited by the natives of newly-discovered countries. It is related in the life of Capt. Cook, that, while he was in New Zealand, he never saw a case of disease among the inhabitants; that, in all his visits to their towns and huts, he did not observe a single person who had any bodily complaint; that he observed with surprise the great number of old men with whom the country abounded, who, although they had lost their hair and teeth, were as cheerful, vivacious, and happy as their grandchildren. It is mentioned as another proof of the health of these people, that their wounds heal with extraordinary facility and rapidity. A man, by accident, got a musket ball shot through the fleshy part of his arm, and it healed so quickly and perfectly that, had not Capt. Cook been aware that no application whatever had been applied to it, he would have been led to think that the art of surgery existed in that country in a state of great perfection. "Water," adds the writer, "as far as our navigators could discover, is the universal and only liquor of the New Zealanders." "It is greatly to be wished," continues he, "that their happiness in this respect may never be destroyed by such a connection with European nations, as shall introduce that fondness for spirituous liquors which has been so fatal to the Indians of North America." On turning our eyes to the last-mentioned country, we see the once athletic, vigorous, and brave Red Indian falling powerless before the contaminating influence of the vices of civilization; and the day is probably not far distant, when the last of his race will sing his farewell hymn to the setting sun, on the top of one of the Rocky Mountains, before he breathes his last, and takes his departure to that happy country in the "far west," where he hopes to revel in all the pleasures of flood and field that would have enchanted him in this lower world. There is no great good in this sublunary scene but is alloyed with a great amount of evil: so it is with civilization. The benefits it confers on mankind are incalculable, but at first sight we are apt to think that the evil counterbalances the good. We see a rude tribe of savages, a brave, in some sense a virtuous, a healthy, and a happy race, brought within the sphere of civilization, and immediately fall a prey to its attendant train of vices. Drunkenness, dissipation, immorality, misery, and disease, will take the place of temperance, sobriety, morality, happiness, and health; and, without the precepts of religion to inculcate self-control, the influence of public opinion to produce moral restraint, or the light of science to warn them of their danger, these wild men of the woods will gradually become extinct.

Does civilization, then, diminish or increase man's liability to disease, or the number of diseases? Does it tend to shorten or prolong the span of human existence? The diseases almost peculiar to civilization are—scarlet fever, syphilis, scrofula, consumptions, cancer, gout, dropsy, palsy, apoplexy, mania, indigestion, hysteria, hypochondriasis, and, in general, all those diseases which have their seat in the brain and nervous system. According to the late Dr. Cullen, the number of diseases which belong to civilized nations amounts to 1,387; of this number, 612 are made up by the class of nervous diseases alone. To prove that *moral causes* greatly contribute to swell the number to this enormous amount, we have only to visit a lunatic asylum, and behold the effects of avarice, of pride, of vanity, of ambition, of disappointed love, of injustice, and inhumanity, in making up the number of its inmates. To show the influence of *physical causes* in promoting disease among civilized nations, we have merely to take into account the close and overheated nurseries among the rich, the crowded and filthy dwellings among the poor, the impro-

per diet and dress, and the premature development of the intellectual faculties, added to hereditary delicate constitutions, in producing the numberless diseases of infancy, childhood, and youth. Again, their pernicious and absurd fashions in dress, their overstimulating diet and cordials, their want of exercise, their eager pursuit after excitement, their indolence during pregnancy, their hot rooms and pampered appetites during childbirth, all open up so many avenues for the invasion of the various diseases incident to females in civilized life; while the effects of hard labour and poverty among the poor, of indolence and debauchery among the wealthy, of intemperance among all classes, and of different trades and professions, sufficiently account for the great increase in the number of diseases among the civilized portion of mankind. The first question, therefore, must be answered in the affirmative—that civilization, by promoting the moral and physical causes, greatly increases, not only the liability of man to disease, but the number of diseases. But, on the other hand, on comparing the past with the present condition of mankind—on comparing the longevity of the inhabitants of ancient and modern kingdoms with the different degrees of civilization enjoyed by each, we are forced to the conclusion, that the progress of civilization tends to lengthen the average of human life, and to promote the greatest happiness of the greatest number; and although a multitude of new diseases follow in its train, still, with the march of civilization, many become less prevalent and diminish in fatality, while others have entirely disappeared. Among the former may be mentioned small-pox, scurvy, rickets, dysentery, and intermittent fever or ague; among the latter, leprosy, the sweating sickness, and the plague. *Leprosy* was so general, and committed such ravages throughout Europe in the twelfth century, that hospitals were erected in many places exclusively for the relief of that disease: it disappeared about the beginning of the sixteenth century. The *sweating sickness* prevailed in England till the end of the sixteenth century; in some seasons, during a month or two in autumn, its mortality was nearly equal to that of the plague. Erasmus ascribes the prevalence and great mortality of these diseases to the "filthy and loathsome" condition of the inhabitants of the cities of Western Europe in those times. They were so dirty, and so poorly fed and clothed, that when any contagious disease made its appearance among them, the havoc it made was dreadful. "The floors of the houses (in the fifteenth century)," says Rankin, in his History of France, "being commonly of clay, and strewed with rushes and straw, it is loathsome to think of the filth collected in the hovels of the common people, and sometimes in the lodgings even of the superior ranks, from spilled milk, beer, grease, fragments of bread, flesh, bones, spittle, excrements of animals," &c.

The first accounts of the *plague* in English annals occur in the year 430. In 1349, it spread from the north-western parts of Asia over all Europe, and became epidemic in England. It swept off more than two-thirds of the inhabitants in some parts of the kingdom, and, on an average, one-half is said to have perished. In the city of London, which was then in a most filthy and crowded state, the streets very narrow, dirty, and unpaved, the houses low and badly ventilated, the sewerage and the supply of fresh water very deficient, 100,000 persons died in that year from this cause alone. In 1562, more than 20,000 died; in 1592, 36,000; in 1625, 35,000; in 1636, 10,000; and in 1665, 68,000. In 1666, the great fire took place. The greater part of London was reduced to ashes; a new city was built; the streets were widened, paved, and drained; the houses constructed on new and improved plans; a supply of pure water was obtained; sewers were formed: the plague thereafter began to languish, and, in 1679, it finally disappeared.

Any one in advanced life has merely to refer to his own observation, or to the recollection of the tales told him by his ancestors of the prevalence and mortality of *small-pox* in their days, to prove the great diminution of this disease by vaccination. The inestimable benefits of vaccination are checked by the neglect, and, in some instances, by the caprice, of the lower classes; so that, in countries where this measure is not enforced by the government, a proportion of deaths still arise from small-pox. In London, about 1 in 40 die from this cause; in Prussia, about 1 in 12; while in Sweden, where vaccination is enforced by law, the following official return places the efficacy of the measure in the strongest possible light:—

| | | | |
|---|---|---|---|
| In the year | 1779 | the small-pox destroyed | 15,000 persons. |
| ...... | 1784 | ...... ...... | 12,000 ... |
| ...... | 1800 | ...... ...... | 12,800 ... |
| ...... | 1801 | ...... ...... | 6,000 ... |
| ...... | 1822 | ...... ...... | 11 ... |
| ...... | 1823 | ...... ...... | 37 ... |

The London *Bills* of the seventeenth century, show that the mortality from *scurvy* was then considerable. By a continuous supply of *fresh* vegetable and animal food on land, and, failing these, of lemon juice on sea, combined with habits of cleanliness and sufficient clothing, this disease is now rarely seen.

That *rickets*, and other diseases of children, have greatly diminished with the progress of civilization, there can be no doubt whatever. The following table of the ratio of infant mortality in London for 100 years, shows that this mortality has been constantly on the decline:—

| Periods. | Ratio of deaths per 100 births, under 5 years of age. |
|---|---|
| From 1730 to 1749, | $74\frac{1}{2}$ per cent. |
| ... 1750 to 1769, | 63 ... |
| ... 1770 to 1789, | $51\frac{1}{2}$ ... |
| ... 1790 to 1809, | $41\frac{1}{2}$ ... |
| ... 1810 to 1829, | $31\frac{4}{5}$ ... |

Accurate tables of the registration of deaths have been preserved at Geneva since 1560; from which we find, that in the middle of the sixteenth century, half the children born did not arrive at the age of six years; in the seventeenth century, the probability of life to a newly-born infant was about $11\frac{1}{2}$ years; in the eighteenth century, it increased to above 27 years; while at the present day, according to the Carlisle tables of the laws of mortality, the probability of life to every newly-born infant in Britain is upwards of 38 years.

Many parts of Britain were subject, in olden times, to the yearly recurrence of *intermittent fever* or *ague*. In London it was very frequent and very fatal. James I. and Oliver Cromwell both died of ague contracted in London. The town of Portsmouth also, being built on the low marshy island of Portsea, was formerly very subject to fever and ague; but since it was paved and drained in 1769, the disease has disappeared, while Hilsea, and other parts of the same island, continued to be affected till 1793, when the disease was visibly mitigated by the formation of a drain. In many parts of Scotland, also, the inhabitants were annually visited with an attack of fever and ague; but the improved sewerage of towns, the drainage and cultivation of bogs in the country, together with the application of lime, have all materially contributed to dispel the cause of the disease; and agues, unless in a few low-lying marshy districts in England, have all but disappeared from Britain. In London, about 180 years ago, according to Sydenham, 66 out of every 100 deaths arose from simple fevers alone; while, at the present day, the whole mortality from epidemic, endemic, and contagious diseases, does not amount to one-fourth of the total number of deaths from all causes.

Even the climates of different countries have changed and become more healthy by the progress of civilization. Two thousand years ago, England, France, and Germany possessed the hot short summers, and the long, cold, and stormy winters, which prevail in Canada and Chinese Tartary at the present day. Cæsar informs us that the vine could not be cultivated in Gaul, on account of the severity of the cold in winter. The reindeer, which cannot now exist in a more southern climate than Lapland, was then an inhabitant of the Pyrenees. The river Tiber was frequently frozen over at Rome, and the ground covered with snow for weeks together, which now scarcely ever happens. Fairs have been held on the Thames at London, so thick was its icy covering

in former times; such a circumstance would now be looked upon as a most remarkable occurrence. Countries become more salubrious by the increase of the population, and the prosperity and progress of agriculture; and it is only by continued industry that this salubrity is maintained. No sooner had the lands around Rome been allowed to go out of cultivation, than *ague* was immediately observed to increase; while in North America, the advance of agriculture, by draining, cutting down trees, and improving the soil, has produced such a marked effect in promoting the healthiness of the climate, that localities which were speedily fatal to the early settlers, have now become perfectly salubrious. There can be no doubt that the climate of Europe has undergone a great change, and it seems equally certain that America will partake of the same amelioration when the same amount of industry has been expended on her soil.

That the mean duration of life, then, has been lengthened in every civilized nation, can be no longer doubted. If we examine the data of Dr. Villermé, and compare the rates of mortality in France at different periods, we will find longevity increasing in proportion to civilization. In the fourteenth century, the annual mortality in Paris was 1 in 16 or 17; in the seventeenth century, it was 1 in 25 or 26; and it is now 1 in 32 or 33, while among the higher classes it is only 1 in 42. The increase of commercial and agricultural industry having greatly multiplied the comforts of the working classes, enabling them to procure larger dwellings, a more abundant supply of wholesome food, more comfortable and more frequent changes of clothing, together with a sufficient supply of fuel and pure water; the progress of medical and scientific knowledge having taught men the advantages of cleanliness and ventilation, of draining marshes, of constructing sewers, of widening and cleansing streets, and of bestowing a more enlightened care on infancy, and a more rational treatment of disease having been adopted—many diseases have been mitigated, others completely banished from the land, and, altogether, man's term of existence has been sensibly prolonged. A medical writer observes, "that the *causes* which shorten life are generally those which render it miserable; and that, wherever a people enjoys a higher degree of prosperity, of rational freedom, and of moral dignity, there also will a greater number of individuals reap the full harvest of their years," corroborating our remarks in a former chapter. It is therefore incumbent on every writer of a popular branch of medical science, to point out these causes, so as to contribute his mite towards lessening the amount of human misery, and conducting the feeble and unfortunate in safety to the natural boundaries of their present existence.

Medical writers are in the habit of dividing the causes of disease into *predisposing* and *exciting*. By a *predisposing* cause, they mean any cause acting on the constitution of an individual, rendering him more susceptible of actual disease, than if that cause had not been in operation. By an *exciting* cause, they mean whatever directly gives origin to a disease. For example, suppose a medical student to lead a life of dissipation, and weaken his constitution by vicious habits; and suppose him to visit the wards of an hospital, where he would be exposed to the contagion of typhus fever, in all probability he will become a victim to the disease; whereas, had his constitution been unimpaired, his chances of escape would have been increased sevenfold. The dissipated habits are the *predisposing* cause, the contagion of fever the *exciting* cause, in this by no means rare case.

The *predisposing* cause is that which renders the body more liable to become diseased on the application of an exciting cause.

The *exciting* cause is that which actually excites disease in the body.

A knowledge of these *exciting* and *predisposing* causes is of the utmost consequence in enabling us to escape the liability to disease. By carefully avoiding the *exciting* causes, we are enabled to preserve our health even with a strong hereditary predisposition; and, on the other hand, if we have a knowledge of, and can avoid the acquired, or mitigate the hereditary *predisposing* causes, disease may be averted, even exposed to the risk for a time of powerful *exciting* causes. A person may inherit that peculiar conformation of body, and that physical constitution, from his ancestors, which predisposes him to apoplexy; and though he cannot remodel the construction of his body, nor infuse new blood into his veins, still, by avoiding the exciting causes, by observing the strictest simplicity and regularity in his diet and regimen, and by guarding against that cause which, above all others, not only augments but originates a predisposition to the disease—*intemperance*,—he may not only escape falling a victim himself, but he may transmit to his children a far slighter hereditary taint than his own of that predisposition which he received from his progenitors. Again, we know that any influence which *debilitates* the constitution or vital powers, such as long fasting, excessive evacuations, fatigue, a last night's debauch, want of sufficient exercise in the open air, want of sufficient sleep—in fine, whatever wastes the bodily strength—is a powerful *predisposing* cause of fevers and other contagious diseases; by avoiding these predisposing causes, by a proper quantity of nutritious food, sleep, exercise, ablution, by keeping up the bodily strength to a maximum of vigour, an individual may escape these noxious contagions. It is to these means chiefly that medical men trust to protect them from contagion in their professional intercourse with the sick, for they well know, that in proportion as the body is weakened and debilitated by exhausting influences, it yields the more readily to the exciting causes of disease, such as contagion, malaria, wet, cold, &c.; and that by strengthening the constitution, and avoiding all causes of debility, they can walk in comparative safety amidst the pestiferous influences by which they are surrounded.

In detailing the *physical causes* of disease, we shall first notice *atmospheric causes*, which may either be predisposing or exciting according to circumstances.

1.—*Extremes of heat and cold, and sudden vicissitudes of temperature.*

What are the effects of excessive heat and cold upon animal life? We know their effects upon vegetable life: in summer, the sap of plants circulates, and it circulates with more or less rapidity in proportion to the degree of heat; in winter, the circulation of the sap is slow in proportion to the degree of cold, till, in severe frost, it is almost in a state of stagnation. In summer, while the sap circulates, the plant is clothed with foliage—it grows; as this circulation becomes less vigorous in autumn, the leaves fall off—the growth is repressed. The warmer the climate, therefore, the more luxuriant the vegetation, and *vice versa*. There is a considerable analogy in this respect between plants and animals: as heat stimulates the circulation of the sap in plants, so does it stimulate the circulation of the blood and other organic functions in animals. In warm climates, with the temperature ranging from 80 to 100, and even 120 degrees of Fahrenheit's thermometer, we find, along with a luxuriant vegetation, a dense population, their organic functions energetically performed, their span of life abridged, they arrive quickly at maturity, and as quickly fall to decay: a female is a mother at 12, a grandmother at 25, and an old woman at 35; here animals and vegetables arrive at a large size. In arctic regions, on the contrary, the inhabitants are few and thinly scattered, animals and vegetables are stunted in growth, the stature of man is only 4 to 5 feet, the powers of life are languid, and he lives to a much greater age. But while heat stimulates the *organic* functions, such as the circulation of the blood, it at the same time depresses the *animal* functions of the body, producing deficiency of nervous energy, lassitude, and disinclination to bodily and mental exercise. Cold, on the other hand, depresses the *organic* functions of the body; and when *very* intense, and accompanied with fatigue, it depresses all the vital powers, producing effects similar in appearance to those of intoxication, a disposition to sleep, coma, and ultimately death. A moderate degree of cold, combined with exercise and sufficient clothing, has an invigorating and exhilarating effect on the mind and body; it gives a buoyancy, a cheerfulness, and an elasticity to the spirits, and a sensi-

bility, an energy, and acuteness to the intellectual faculties, which are totally unknown to the native of a relaxing climate within the tropics.

The most prominent diseases of tropical climates are—inflammation of the liver, dysentery, cholera, and yellow fever; and one peculiarity of these diseases is, that, as might be expected from the stimulating influence of heat on the vital functions, they run a very rapid course. It is, indeed, no unusual circumstance to see a friend in apparently good health early in the morning, to hear of him being attacked by cholera or acute dysentery during the day, and to be asked to attend his funeral the same evening. There is now, however, much less importance attached to the influence of climate in the production of disease than formerly; it being well known, that man is endowed with the peculiar power of accommodating himself to almost every climate where fortune may place him; and that his liability to, or immunity from, disease in a warm climate, will depend, in a great measure, on the prudence by which he is governed. A great proportion of the deaths among Europeans in warm climates, arises from their gross neglect in avoiding and guarding against the obvious causes of these diseases; they have not sufficient self-control to restrain themselves from a licentious mode of living, from diet the most unsuitable, from indulging in spirituous liquors, and from the grateful but dangerous exposure to the cold evening air, after the burning heat of a tropical sun.

Dogmatic rules, either for the preservation of health, or for our guidance in any of the common affairs of life, will never be borne in mind so easily, nor will they command obedience so strongly, as when we see clearly the propriety of these rules, from knowing the grounds upon which they are founded. To make the effects of heat and cold, therefore, and of sudden variations of temperature in promoting disease, thoroughly understood, it will be necessary to explain a few of the physiological peculiarities of the structures which are affected by their influence.

It is well known that the arteries are tubes leading from the heart, conveying the living fluid—the blood—to all parts of the machine, to nourish and sustain the different organs and tissues of which it is composed. When these arteries arrive at their destination, they become so infinitely subdivided, and their branches communicate so freely together, that every organ and texture of the body—heart, lungs, liver, kidney, brain, bone, muscle, skin, &c.—is permeated by an exceedingly close network of extremely small blood-vessels, called *capillaries*, from *capillus*, a hair. They are the terminations of the arteries and the beginnings of the veins, hence called also *intermediate vessels*.

These capillary or intermediate vessels are only $\frac{1}{3000}$ of an inch in diameter; they cannot be seen but through a microscope; and they are so closely packed together, that the point of the finest needle cannot be introduced through the skin without wounding several of them. From these capillaries, the veins carry the blood, now deprived of its nutritive ingredients and loaded with impurities, back to the heart, to be thence sent on to the lungs, there to be purified, before it be again transmitted through the system.

Besides this capillary network, there is another set of infinitely small tubes which must be taken into account in considering the effects of heat and cold on the surface of the body; these are the perspiratory pores, which perforate the skin in every part, enabling the perspiration to exude either in an invisible vapour, or a visible fluid. These pores are more numerous in some parts of the body than in others, but, on an average, the number of 2,800 is reckoned for every square inch of surface of the skin; and that the perspiration, either in a *visible* or *invisible* form, is incessantly poured forth from these, we can easily prove by holding a piece of very finely-polished metal near any part of the body, and observing it quickly covered with moisture. The amount of fluid exhaled from the skin in twenty-four hours is about 23 oz.; from the lungs, 10 oz.; in all, somewhat above 2 lbs. But the amount of fluid excreted from the skin and lungs, depends upon whatever stimulates the circulation of the blood; the stronger the stimulus either to the general or capillary circulation, the more fluid is given off, and *vice versa*. Two purposes of infinite value to the safety of the system are fulfilled by the cutaneous and pulmonary exhalation: one, to remove from the system a quantity of ingredients which, if allowed to circulate in the blood, would very soon prove noxious to animal life; another, and a most important one, to regulate the temperature of the body. Chemistry tells us that water, at the ordinary temperature of 45°, requires 167 degrees of heat to make it boil, but that more than $5\frac{1}{2}$ times this amount must be expended before it can be converted into vapour or steam. We thus see how beautifully the perspiration is adapted to regulate the animal heat: the more the body perspires, the more does this perspiration, in passing from the fluid to the aeriform state, rob it of its superfluous heat, so as to keep it at a nearly uniform temperature. By this regulating power, man can remain for a considerable time, with perfect safety, in an oven heated far above the temperature of boiling water, while animals that do not possess this perspiratory apparatus would perish in a few minutes. By the same power, and with ordinary prudence, he can withstand the heat of a vertical sun for a lengthened period, and with less injury to his constitution than is generally imagined.

Bearing these things in mind, we can now understand why sudden variations of temperature are so productive of disease. Heat stimulates the capillary circulation of the skin, attracting a great amount of blood to the external parts, and increasing the perspiration from the surface of the body; the exhalation from the lungs, also, is increased or diminished according to the moisture or dryness of the air which is breathed. Now, if we could suddenly arrest these actions—if we could suddenly check the capillary circulation, stop the perspiration, and supply the lungs with moist air, what would be the result? The blood would be repelled upon the internal organs, producing inflammation or excessive action; the exhalation from the skin would be repelled upon the kidneys, that of the lungs upon the liver, or else these fluids would circulate in the system and promote disease; and these noxious effects would be the more powerful, in proportion to the suddenness of their occurrence, and the vigour of the actions of the different organs at the time. Cold causes the external parts to shrink, when very intense, even to the falling off of rings from the fingers, and shoes from the feet; thus arresting all the actions of the blood in the capillary vessels, checking the perspiration, and repelling the force of the circulating current upon the internal organs. In this manner, therefore, cold acts as an exciting cause of disease; and when we add to these effects, that a hot atmosphere becomes saturated with moisture during the day, which, by the evening's cold, falls profusely in the form of dew, thereby checking the exhalation from the lungs, and repelling it upon the liver, giving it a double amount of labour, we may cease to wonder that sudden vicissitudes of temperature should prove such powerful causes of disease.

It is absolutely necessary for the health of the body, that every organ shall perfectly and regularly perform the peculiar duty assigned to it: the liver must secrete its proper quantity of healthy bile, the kidneys their urine, the skin its perspiration, the bowels and the lungs their secretions; otherwise the equilibrium of the whole will be disturbed. But to enable them to perform these offices, they must be supplied with a proper quantity, and not more than a proper quantity, of blood. If the supply to any one of them be checked, and reduced below the natural standard, its secretion is immediately diminished, and either some other organ must take on additional work, or noxious matters, which ought to have been removed from the system, will remain in the blood, and act as a poison. If, on the other hand, the supply of blood to these organs be in too great quantity, they are called into excessive action, their secretions become increased in quantity and vitiated in quality, and inflammation of the organ is frequently the result. This is precisely the effect produced by sudden vicissitudes of temperature. An individual, after being exposed to a heated atmosphere, or to excessive exercise, is perspiring freely, and, in an exhausted state, throws

off part of his clothes, loosens another part, and sits down in the cool refreshing breeze at an open window; what happens? The capillary circulation is arrested, the blood is repelled upon the internal organs, the perspiration is also checked, and an additional demand is made upon some of these organs: if on the intestines, either inflammation is the result, if they refuse to act, or if they do act, there is an attack of diarrhœa, or dysentery; if upon the liver, here again we have inflammation, or an excessive flow of bile, which in its turn affects the bowels, producing a bilious attack, with vomiting or dysentery; if upon the lungs, we have inflammation, or an excessive secretion of mucus, which is denominated influenza, or catarrh; if on the brain, inflammation, apoplexy, or paralysis; if on the kidneys, also inflammation, or an excessive flow of urine; if on the joints, rheumatism; or perhaps the constitution may be so strong, and all the bodily organs may act with such harmony, that the extra duty may be shared between them, and no bad effect may ensue. In nine cases out of ten, however, the individual, from predisposing causes, has some one of his bodily organs weakened, and liable to be affected by so strong an exciting cause, and, in the instance we have supposed, it is certain to suffer. In India, for example, the extreme heat during the day raises into the atmosphere a great quantity of moisture, which, by the evening's cold, becomes condensed into dews and fogs: this cold moist air not only has a pernicious effect, by repelling the blood upon the internal organs, and thus becoming an exciting cause of disease, but also, from its being inhaled into the lungs, it prevents the proper quantity of watery exhalation from passing off from them; and from the sympathy of action which appears to exist between the lungs and the liver, the latter organ is habitually called into over-exertion—hence it is weakened, and predisposed to disease, and, on the occurrence of a sufficiently strong exciting cause, falls a victim to inflammation and its consequences. Again, if we add to these causes of disease which are peculiar to the climate, the well-known influence of stimulating food and drink as a powerful predisposing cause of disease in the liver, kidneys, and intestines, we need not be surprised that the prevailing complaints of Europeans in tropical climates should be diseases of these organs, or that a fatal attack of inflammation of the liver, of cholera, or of acute dysentery, should be the certain consequences of a moderately strong exciting cause.

But not only does cold act as a cause of disease, by contracting the superficial blood-vessels, and repelling the blood upon the internal organs, it tends also to depress the action of the heart, and paralyse the vital energy of the system. As long as the heart's action is kept up, either by the strength of the constitution, by exercise, or by the influence of stimulants, the pernicious effects of sudden changes of temperature are counteracted. The Russians leave their vapour baths, and roll themselves in the snow, or plunge into cold water; arctic voyagers leave their cabins, where the temperature is at 60° Fahr., and go into the open air at 10°, or at zero; others will leave ovens heated far above the temperature of boiling water, and go into the atmospheric air at 50° or even 40°; and in all these instances, with perfect impunity. In such cases, however, the constitution is vigorous, the vital energy is unexhausted, and, though the blood is repelled upon the internal parts, there is sufficient strength to produce reaction, and no bad effects ensue; but if the cold were prolonged beyond a certain point, or if the constitution be weakened by any predisposing cause, so as to be unable to produce reaction, and to return the blood to the surface of the body with sufficient energy, then would the case be totally altered, and the most disastrous consequences would be the result. From this we can understand the injurious effects of cold bathing, if the strength be too weak to produce reaction—which, of course, is the more certainly and quickly produced, the more vigorous and unexhausted the body is at the time; we can also understand why old people and infants, in whom the circulation is weak, are more liable to suffer from the effects of cold, than those in the prime and vigour of life.

## THE ICE TRADE.

It is doubtless well known to our readers, that the commercial importance of Ice has of late been advancing with unwonted celerity, unsurpassed perhaps by any other article of trade, if we except that highly prized commodity, commonly called Guano. The Guano trade has been quite a commercial phenomenon; the rush of a caravan to a stream in the desert could hardly symbolize the eagerness with which that lucrative traffic has been pursued, when once the value of the prize became known. Ships, which lay inert and useless in their berths, gaping their wide holds for a wherewithal to trip it o'er the glassy wave, and ready to burst their well-tarred sides, one would think, with downright indolence—these ships got ready chartered for the famous Ichaboe, and once more was our shipping trade restored to activity. The days of the Guano trade, notwithstanding, are, we fear, numbered; we anticipate that ere long the trade will die a natural death—a death of sheer exhaustion, and that not a vestige of it will be left to posterity, always excepting the wonderful mummy that has been exhumed from the bed where it had lain so long and so comfortably.

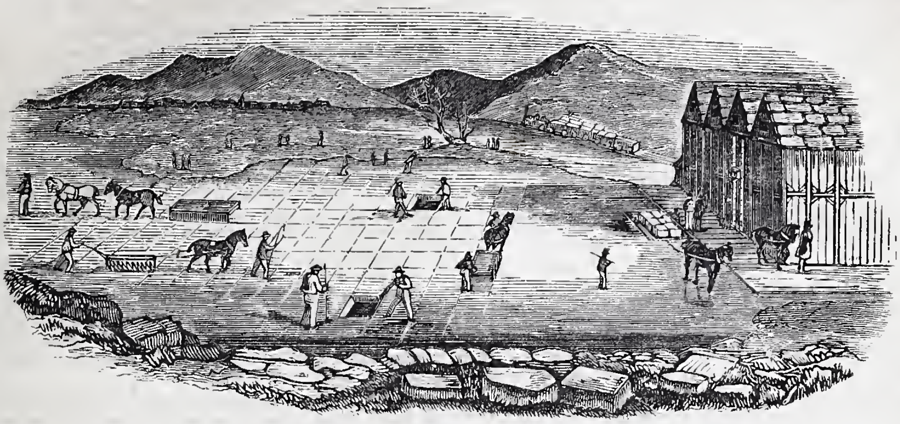
Not so is it with the trade in Ice. So long as the revolution of the seasons shall continue, we may expect the hundreds of thousands of tons annually derived from the surface of the globe. Ice is prepared from water, in Nature's laboratory, by the simplest of means, and, as usual, on a *gigantic* and *liberal* scale. The Ice merchants have only to prepare their instruments, and these of the simplest kind, for the cutting up and transporting of the raw material. Moreover, raw as that material is, it undergoes no preparatory and expensive process for fitting it for public use. Ice, as it is, unadulterated Ice, is used in the kitchen, in the butler's pantry, and on the table, as regularly as any other *necessary* luxury. It is not wonderful, then, that the obtaining and supplying of Ice has called into existence regularly organised *Ice Companies*, and furnished regular employment to a large amount of labouring population.

North America takes the lead in the cultivation of this branch of trade. This need not surprise us, when we recollect the natural facilities offered by the country, in conjunction with the genuine Yankee spirit of enterprise. There are in Boston, U.S., sixteen companies engaged in transporting thousands of tons of this arctic crystal to the East and West Indies, to South America, and other warmer climates, and even to our own country. The "Wenham-Lake Ice Company," in particular, have erected extensive Ice-houses in London and at Liverpool, and have engaged agents in all our principal cities and towns. The annual quantity of Ice shipped from Boston to distant ports amounts to about 50,000 tons, and from Charleston, about 30,000 tons. The expense to the shippers from Boston is about 12,340 dollars, or 1s. 1½d. per ton; the gross receipts 2,570,000 dollars. A few years back a cargo of Ice was sent to the East Indies, where it was exchanged for cotton, weight for weight; the cotton was taken to England, and sold there at a handsome profit. Formerly, Ice was sold in New Orleans for 6 cents (3d.) per pound; now it sells for 1 cent (½d.) per pound; at the same time, more money is made from the increased consumption encouraged by the reduction of price—an admirable instance of the salutary operation of a system of small profits and large returns.

It is a curious fact, that in the transportation of American Ice, even in the heat of summer, it is not sensibly reduced in bulk. This may be attributed to two circumstances—the magnitude and quality of the Ice, and the manner in which it is packed. Ice frozen upon very deep water is much more compact and solid than that which grows on the surface of shallow lakes and streams; and therefore, even when an equal surface is exposed to the atmosphere, the former melts more slowly than the latter. Now, the Ice in America is derived from lakes of great depth, sometimes as much as 200 feet; and the severity of the cold, which in winter falls several degrees below zero, combined with this fact, renders the Ice from the American lakes famous, not only for its solidity, but for its magnitude likewise, being allowed to grow till it attains 12 inches in thickness. Thus, the Ice being much thicker than any that is usually producible in this country, it exposes less amount of surface to the deliquescent action of the air. When the Ice is made up for transportation, it is employed in ships as ballast, for which purpose it is carefully cut up into blocks to fit the hold, and covered with saw-dust, straw, and charcoal dust, all non-conductors of heat, under cover of which it is conveyed on the voyage. When the Ice is regularly shipped as cargo, being cut into blocks, it is packed on board the vessel, in thin air-tight timber boxes, with straw and hay. In this manner it is conveyed, without loss, to the most distant quarters of the globe.

The Ice now imported to this country is obtained from the

Wenham Lake, in the state of Massachusets, 18 miles from Boston: it occupies a very elevated situation, embosomed among hills majestic and rugged, has no inlet whatever, but is fed entirely by springs which discharge themselves nearly 200 feet below the surface. On the verge of the lake the Company's Ice-house is situated, covered by iron roofs, over an area of 100 feet square, and capable of storing 20,000 tons of Ice. It is built of wood, with double walls, two feet apart, all around; the two feet space being filled entirely with saw-

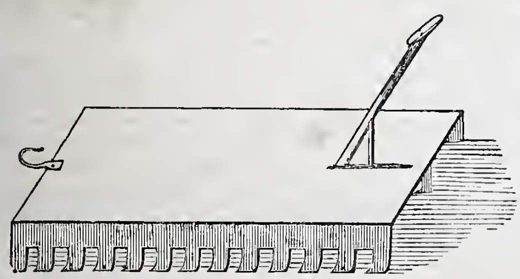


View of the Ice-Cutting on Wenham Lake.

dust, a complete preservative is had from the effects of the external atmosphere, the Ice remaining entirely unaffected by temperature, and preserving its condition for an indefinite period of time.

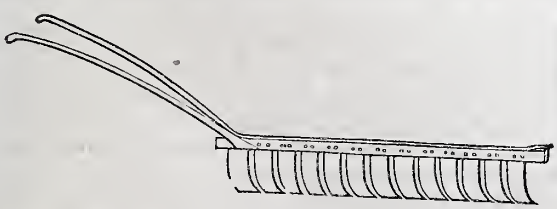
The machinery employed for cutting the Ice is quite unique in its way, and was invented expressly for the purpose. It is worked by men and horses, in the following manner:—

From the time when the Ice first forms, it is carefully kept free from snow until it is thick enough to be cut; that process commences when the Ice is a foot thick. A surface of some two acres is then selected, which at that thickness will furnish about 2000 tons; and a straight line is then drawn through its centre from side to side each way. A small hand-plough is pushed along one of these lines, until the groove is about three inches deep and a



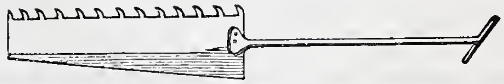
Ice Marker.

quarter of an inch in width, when the "Marker" is introduced. This implement is drawn by two horses, and makes two new grooves, parallel with the first, 21 inches apart: the guage remaining in the original groove. The marker is then shifted to the outside groove, and makes two more. Having drawn these lines over the whole



Ice Plough.

surface in one direction, the same process is repeated in a transverse direction, marking all the Ice out into squares of 21 inches. In the meantime, the "Plough," drawn by a single horse, is following in these grooves, cutting the Ice to a depth of six inches.



Ice Saw.

One entire range of blocks is then sawn out, and the remainder are split off toward the opening thus made with an iron bar. This bar is shaped like a spade and is of a wedge-like form.

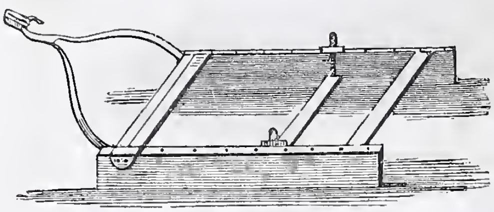
Splitting Bar.

When it is dropped into the groove, the block splits off; a very slight blow being sufficient to produce that effect, especially in very cold weather. The labour of "splitting" is slight or otherwise, according to the temperature of the atmosphere. "Platforms," or low tables of frame-work are placed near the opening made in the Ice, with iron slides extending into the water, and a man stands on each side of this slide armed with an "Ice Hook." With this

Ice Hook.

hook the Ice is caught, and by a sudden jerk thrown up the "Slide" on to the "Platform." In a cold day everything is speedily covered with Ice by the freezing of the water on the platforms, slides, &c., and the enormous blocks of Ice, weighing some of them more than two cwt, are hurled along these slippery surfaces, as if they were without weight. Beside this platform stands a "Sled" of the same height, capable of containing about three tons, which, when loaded, is drawn upon the Ice to the front of the storehouse, where a large stationary platform, *of exactly the same height,* is ready to receive its load; which, as soon as discharged, is hoisted, block by block, into the house, by horse-power. This process of hoisting is so judiciously managed, that both the taking up of the Ice, and the throwing it into the building, are performed by the horse himself. The frame which receives the block of Ice to be hoisted, is sunk into a square opening cut in the stationary platform, the block of Ice is pushed on to it, the horse starts, and the frame rises with the Ice until it reaches the opening in the side of the store-house ready for its reception, when, by an ingenious piece of mechanism, it discharges itself into the building, and the horse is led back to repeat the process.

Forty men and twelve horses will cut and stow away 400 tons a-day. In favourable weather 100 men are sometimes employed at once. When a thaw or a fall of rain occurs, it entirely unfits the Ice for market, by rendering it opaque and porous; and occasionally snow is immediately followed by rain, and that again by frost, forming *Snow-ice*, which is valueless, and must be removed by the "Plane."

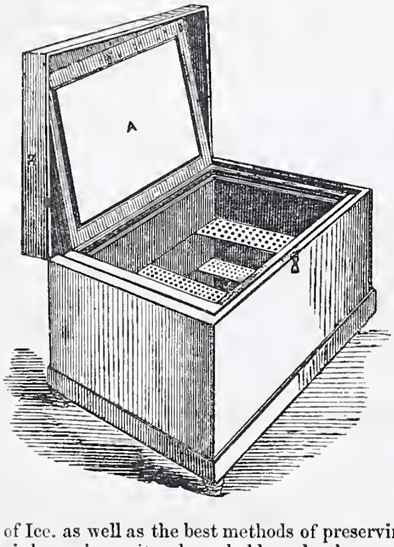


Ice Plane.

The operation of "planing" is somewhat similar to that of "cutting." A plane, guaged to run in the grooves made by the "marker," and which shaves the Ice to the depth of three inches, is drawn by a horse until the whole surface of the Ice is planed. The chips thus produced are then scraped off, and if the clear Ice is not reached, the process is repeated. If this makes the Ice too thin for cutting, it is left *in statu quo*, and a few nights of hard frost will add *below* as much as has been taken off *above*.

In addition to filling their Ice-houses at the lake and in the large towns, the Company fill a large number of private Ice-houses during the winter—all the Ice for these purposes being transported by railway. It will be easily believed that the expense of providing tools, building houses, furnishing labour, and constructing and keeping up the railway is very great, but the traffic is so extensive, and the management of the trade so good, that the Ice can be furnished, even in England, at a very trifling cost.

We, in Britain, have as yet but an imperfect idea of the various




applications of Ice. as well as the best methods of preserving it. In America, Ice is becoming quite a household word; they would consider their domestic arrangements incomplete did they want a "Refrigerator" or portable ice-house, in which they were to lay past their etceteras for occasional use. The annexed illustration represents the refrigerator with the lid open. It is provided with perforated shelves, which are capable of sliding, under which the Ice is placed, and upon which wines, fruits, and provisions are placed and preserved, at a low temperature, without coming in contact with the Ice. The chest is constructed like the large Ice-stores, consisting of double bottom, sides, and lid, filled up with a non-conducting substance, as saw-dust or, preferable, charcoal. A and B are the two lids. A, when closed, renders the interior air-tight. B, is the outer lid, forming part of the external chest, which, altogether, appears as a handsome piece of domestic furniture. In this chest, then, the housekeepers in America, throughout the warm season, place their fruits and provision of every kind, preserving, even for weeks, if necessary, large joints of meat, and other consumables. A block of Ice, weighing a few pounds, placed in the bottom of this provender box, will preserve its contents at a uniform temperature, very little above the freezing point, for several days together.

The perfect purity of American Ice fits it for table use, and accordingly it is the constant practice there to mix it with water or milk, for drinking, to dilute wines and spirits with it, and to place it on the table in direct contact with butter and jellies. In our hotels, taverns, and confectionaries, the famous American drinks are beginning to be regularly manufactured for the thirsty traveller in midsummer, as well as for the heated pedestrians in town. Indeed, it has been averred that they can be no other than the vaunted nectar of the immortals. The very mention of "Sherry Cobblers" and "Mint Juleps," names so true to nature and so characteristic of transatlantic humour, vividly recalls to our imagination the sparkling cup, and the tuberose medium of imbibition, no other than a straw, when, as an era in our eventful lives, we were heartily in love with *drunk*, and therefore *immortal, cobblers.*

We crave pardon of our less enthusiastic readers for offering the following recipes, short and sweet:—

"A Sherry Cobbler is made with a wine glass and a half of sherry, two teaspoonfuls of powdered white sugar, a few pieces of lemon peel; fill the tumbler with pounded Ice (to pound it, put it in a cloth, and beat with a mallet), then pour it from one tumbler into another, until the sugar is dissolved: drink through a clean straw."

"A Mint Julep is made of equal parts of rum and brandy (sugar as before), using leaves of mint instead of lemon peel: mix, and drink as the cobbler."

## HORIZONTAL DOUBLE CYLINDER AIR-PUMP.

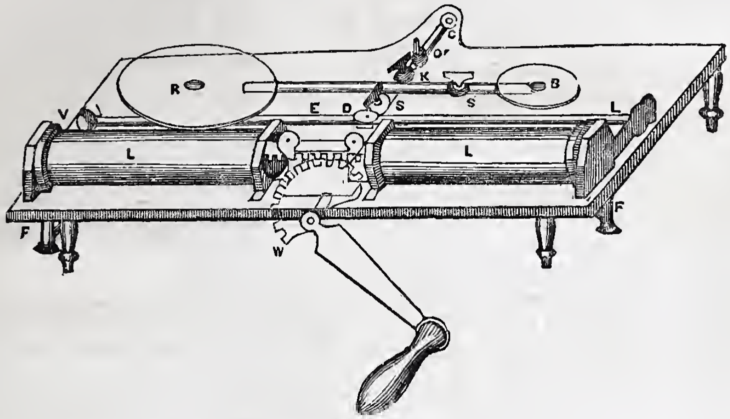
Among the various forms of apparatus employed, none is more generally useful than the air-pump. By it the first and most familiar experiments of the school-room are exhibited. The most profound analytic chemists find its frequent use necessary. Some instruments are valuable for purposes of illustration only, others are confined to the laboratory of research. The exhauster and condenser is indispensable to both. Any modification of, or improvement in this instrument, therefore, is a matter of interest, not only to the man whose sole pursuit is science, but to all who are engaged in studying or illustrating the simplest truths of experimental philosophy.

It is not a little extraordinary, that while nearly every species of apparatus has been improved by modern ingenuity, the air-pump retains the form given it by Boyle but a few years after the original invention by Guericke, and nearly two centuries ago. Hooke, Hawksbee, and Smeaton, enlarged, introduced metallic valves, and made it double acting, but they left its general appearance unchanged. Their improvements are not extensively employed, and, if desired, are as capable of application to the instrument figured opposite as to that of Boyle.

Probably all users of the common form have been made sensible of its want of stability and portability. These evils being sorely felt by the writer while engaged in lecturing, he determined, if possible, to remove them, and, before the close of the season, invented, and, during the following summer, constructed the subject of this article. It has been in use for several years, and has received the unqualified approval of many impartial scientific men, and some of the best makers of philosophical apparatus in the country.

The objections that obtain against the old form arise chiefly from the upright position of the barrels or cylinders. This necessarily throws the pinion twelve or more inches above the point of support. The handle placed on the projecting axis has a constant tendency, while the operator is working the pump, to tilt it outwards, so much so as frequently, during rapid exhaustion, to require the steadying hand of an assistant. This leverage outwards, and the consequent instability, are especially annoying whilst using the barometer guage Again, the most eligible height of table for the display of apparatus, by elevating the handle, renders the work of exhaustion an exceedingly laborious one, and the perpendicular cylinders and pump-head

form an inconvenient barrier between the operator and the glass receiver, especially if the experiment is performed on the guage-plate; a footstool but poorly compensates for this height. Finally, the air-pump, always one of the most expensive items of the laboratory, is rendered so, to some extent, by the cost of the double rack, pump-head, and brass columns that support it. On each of the points named, the horizontal double-cylinder pump is believed to possess great superiority.




*Description.*—In the figure, L L represent the barrels, the enlarged ends of which are let into the board and bolted through to insure stability. There is *one* rack, the two pistons being attached to its extremities. A portion of the rack is exposed at T, The semi-piuion, W, works in cast strips, or gudgeons, attached to the bottom of the board with screws, which, passing through, terminate in the rack guides, one of which is seen above. The forward gudgeon is so cast as to receive the end of the clamp, which secures the pump to the table. The semi-pinion works upwards through a slot cut in the board, and of course between the rack guides. The upper extremities of the guides are perforated to receive rollers, against which the baek of the rack may work when necessary. None have yet been required. To the axis of the semi-pinion the handle is attached in the usual manner. The piston may be either solid or valved, and the cylinders may communicate with the plates, R and B, in the way most approved by the maker. In the pump from which the sketch is taken, the pistons are solid. The farther extremities of the cylinders bear female screws, which connect with corresponding male screws on the block. On the posterior portion of each block is cut a female screw; the male of which bears the valve, of course opening inwards, V V. On those portious of the block which project into the board are cut male screws, bearing valves opening outwards. Perforated nuts over these secure the blocks to the board, and the valves against injury. At V V, is attached the tube leading from the plates, D, Is the screw for restoring atmospheric pressure. The general stop-cock, S, connects this with the parallel tube, which, bearing the guage-cock, S', forms at pleasure a communication between the plates.

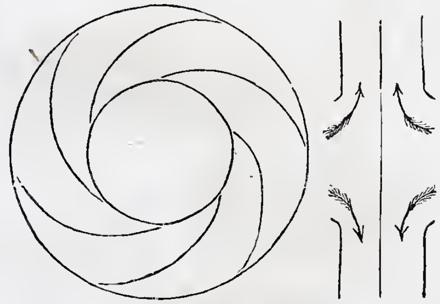
The original of the figure both exhausts and condenses. The remaining letters refer to the parts used in condensing. This is effected by simply connecting, by means of tubes under the board, the valves, F' F, with a third tube passing upward to the stop-cock, K. Then the air drawn in at R will be condensed in a receiver screwed on C. Those familiar with Pneumatic Chemistry need not be told of the facilities thus afforded for the transfer of gases. The condensing guage is borne by the screw, G. To the working philosopher, it is unnecessary to amplify the advantages that result from lowering the centre of motion to a level with the points of support, bringing *both* plates directly under the operator's eye, and presenting, at about the cost of an ordinary exhausting pump, an instrument furnished with all the facilities for exhaustion, transfer, and condensation, without any shifting of parts.

## APPOLD'S PRIZE CENTRIFUGAL PUMP.

This machine is intended for draining marshes, the principle of its action being the imparting a rotatory motion to a vessel of a particular form, whereby a body of water is projected from the centre of motion, just as the drops would fly outwards from a mop when twirled about.

The pumping instrument, which is 12 inches in diameter and 5 inches deep, is suspended on a horizontal axis, and immersed below the level of the water. It consists of two circular plates, having each central apertures of 6 inches iu diameter. The space between them is divided into six compartments by the spiral plates, or blades, fig. 1; and between the two outer discs there is another

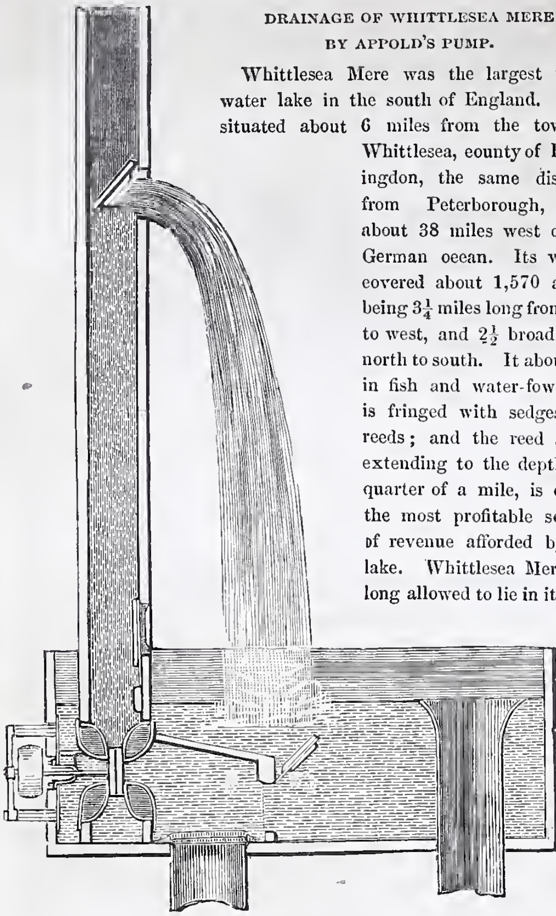
Fig. 1.



disc placed to prevent the currents, which enter through the central apertures, from coming in contact with each other. The water rushes in through the two apertures in the centre of the outer plates; then, by turning the instrument in the proper direction, the several spiral blades force the water to flow towards the circumference. New water continues to enter by the outer apertures, taking the place of that which has been removed; thus a continued flow is kept up from the centre to the circumference; and, as the velocity increases, centrifugal force is added to the action we have attempted to describe.

To make this centrifugal effort available as a lift, the disc is placed near the bottom of a vertical trunk, as shown in the engravings, and the impetus caused by the velocity with which the water rushes outwards forces it to ascend to the desired height. Fig. 2 is a vertical section. Fig. 3 is a front view.

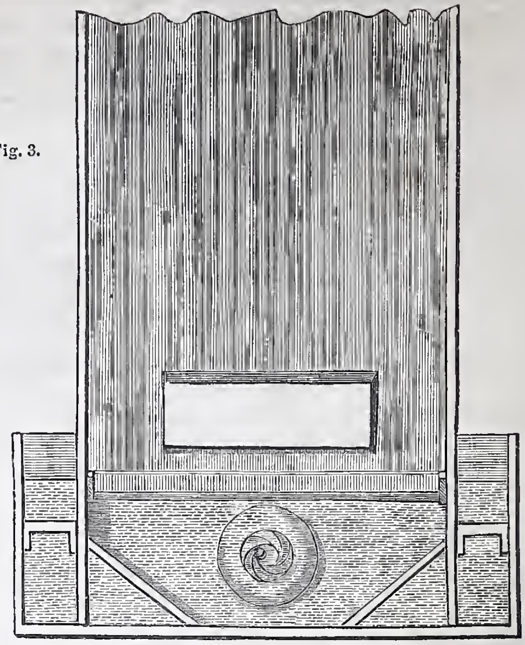
Mr. Appold's pump makes 600 revolutions per minute, discharges its contents 1,400 times, and does a duty of 70 per cent. on the power employed.



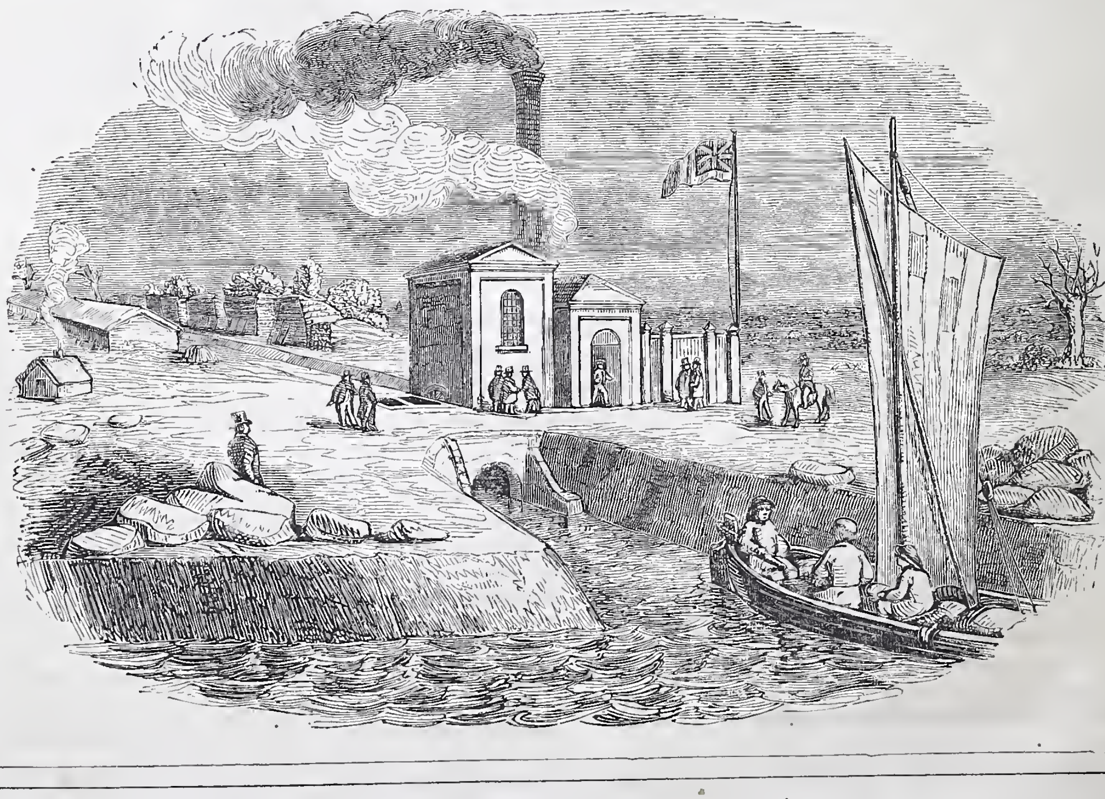
### DRAINAGE OF WHITTLESEA MERE BY APPOLD'S PUMP.

Whittlesea Mere was the largest fresh-water lake in the south of England. It is situated about 6 miles from the town of Whittlesea, county of Huntingdon, the same distance from Peterborough, and about 38 miles west of the German ocean. Its waters covered about 1,570 acres; being $3\frac{1}{4}$ miles long from east to west, and $2\frac{1}{2}$ broad from north to south. It abounded in fish and water-fowl. It is fringed with sedges and reeds; and the reed shore, extending to the depth of a quarter of a mile, is one of the most profitable sources of revenue afforded by the lake. Whittlesea Mere was long allowed to lie in its wild

Fig. 3.



state, though, by means of the great level drainage, the neighbouring fen country has gradually undergone a great improvement. Now, however, its drainage is commenced in good earnest. The total amount of land to be reclaimed from the marsh is upwards of 3,000 acres. Mr. Wells, of Holme-wood House, Hants, and Redleaf, Kent, the proprietor of by far the greatest portion of the Mere, has employed for its drainage one of Appold's centrifugal pumps. This is the first that has been erected on so large a scale, being $20\frac{1}{4}$ times larger than the model shown at the Great Exhibition. The completion of its erection was anxiously looked forward to by the public, as the success of the experiments then made would determine whether or



Mr. Amos the engineer, Mr. Wells, and Mr. Fryer, chairman of the Bedford Level, were present, with others of the commissioners, and many practical men, besides those who, from long experience in the peculiar system of drainage which the fens require, were qualified to form a decisive opinion on the capabilities of Mr. Appold's invention.

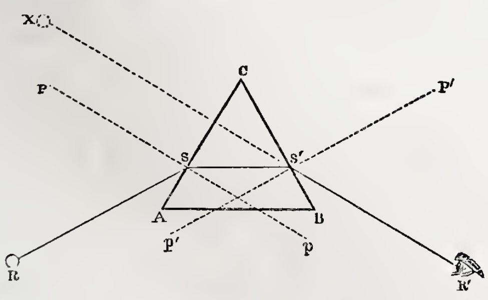
The Centrifugal Pump was put through a series of experiments, all of which were completely successful and satisfactory. The wheel is four feet six inches in diameter, and, after a few revolutions, the water rose to the top of the sluice, and was hurled over the gauge boards in a roaring torrent, which fell 16,521 gallons per minute. Working under a five-feet lift, the machine discharged about 74½ tons of water per minute; but when the lift was reduced to three feet, by the removal of some of the gauge boards, the volume of water discharged was 101 tons per minute. The pump is connected by a wheel gearing to a steam-engine of twenty-five horse power, working on the high-pressure expansive and condensing principle, with two cylinders. The boiler is very simple in construction, though, at the same time, possessing the form of the greatest strength, none of its parts being of large diameter, and presenting no flat surfaces. Its pressure is about 3,500 tons, being about thirty-five pounds per square inch. The Centrifugal Pump receives the water from the principal drain, called the Holme Lode, and passes it on, under a bridge, to one of the main drains of the Bedford Level, termed the New Cut, but which is, in fact, a navigable river.

## NATURAL PHILOSOPHY AND CHEMISTRY.

### CHAPTER IX.

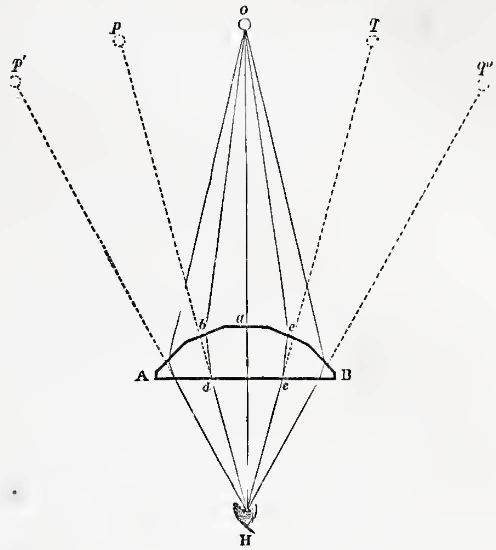
#### REFRACTION OF LIGHT BY LENSES.

It has been shown that when a ray of light falls perpendicularly upon the surface of a refracting medium, bounded by parallel sides, as a plate of glass, it undergoes no change of direction; but, in every other line of incidence, it suffers refraction according to the law already detailed. It is, however, necessary to consider the circumstances which attend refraction when the sides of the refracting medium are not parallel to each other. A good illustration of this is afforded by the triangular prism, which, we may suppose, is formed of glass, and having its sides inclined to each other at angles of 60 degrees. A cross section of such a prism is shown in the subjoined figure, of which A B is



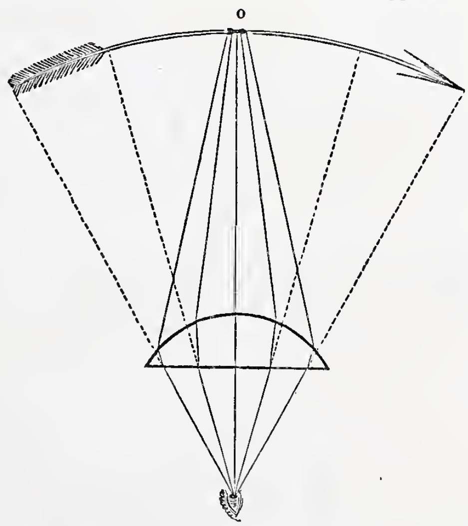

the base, and A C and C B the refracting sides. If a ray of light, R, fall upon the side A C at S, it will be refracted from its course towards the base, and, consequently, towards the direction of P *p*, which is a perpendicular to A C; and on emerging at S', it will be bent *away* from S' P', which is perpendicular to C B, and thus reach R' with its original deviation doubled. Hence, to a spectator at R', an object at R would appear at X; for the refracted ray S' R', if produced, will reach X; and objects, as already observed, always appear to be situated in the direction of the rays which eventually reach the eye.

The same principle is very beautifully shown in the multiplying glass—that is, a glass having a number of facets cut upon it at angles to each other. Supposing A B to represent a section




of such a glass; and that there is a small body—a small coloured bead for instance—placed at O; an eye placed at H observing the object in the direction of the rays which eventually reach it, will perceive as many objects as there are facets cut upon the glass. Thus, the ray O *a* which suffers no refraction will show the object in its true place at O; but the ray O *b*, falling obliquely on the plane *b*, will be refracted in the direction *b d*, and on leaving the glass at *d*, will pass to the eye in the direction *d* H, and will make the object appear at *p*. In like manner, the ray O *c* will be refracted to the eye in the direction C H, and the object O will appear at *q*, and so on of any number of facets. If the eye were at O, and the object at H, the result would still be the same.

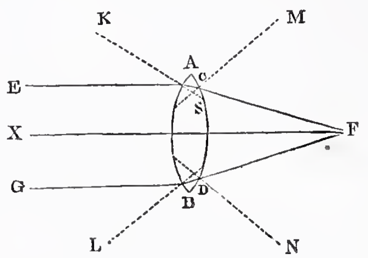
When the surface of such piece of glass is uniformly convex, the phenomenon is very different. Instead of a multiplication of objects, there is a simple enlargement, as depicted in the subjoined figure. The glass, A B, is, in this case, supposed to be a




small segment of a sphere; and the rays which fall upon it from the object O being refracted according to the law pointed out in the case above, they ultimately meet in a point. An eye placed, therefore, at this point of convergence, receiving rays from all the points of the object, perceives these points to be situated in the direction of the lines which ultimately enter the eye, and the whole object appears to be magnified in proportion to the rapidity

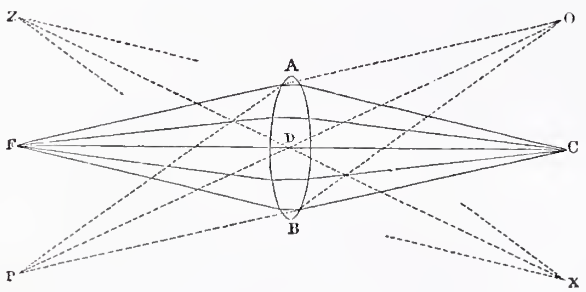
of convergence. It may indeed be inquired, why such a glass does not, like the multiplying glass, give only a multitude of images, answering to the multitude of faces of which, we may suppose, the convex surface of the glass to be composed? The answer is very simple. In the multiplying glass, every facet bends *a whole set* of rays capable of forming a distinct and complete image; but the magnifying glass described has none of its faces large enough to bend more than a single ray. The rays which flow from the object are therefore not separated into sets, but are bent individually, and concentrated to a point, at which, if an eye be placed, it receives the whole multitude of rays in the same order as they flow from the object; they are, however, refracted, and the points of the objects appearing in the directions of the straight converging lines, a single image only appears, magnified, however, in the proportion of the angles of convergence.

A glass, ground convexly on both sides, answers the same conditions as that described. Thus, supposing that three parallel rays—and all rays coming from the sun may be reckoned parallel—fall upon the glass A B; the ray X will pass on without refraction; but the rays E and G, meeting the surface obliquely, will be deflected from their paths *toward* K and L, the perpendiculars to the points



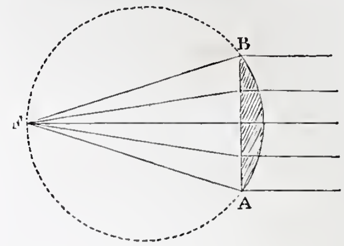

of incidence; and on emerging at C and D into the air a rarer medium, they are refracted again, but in a contrary direction; namely, *from* the perpendiculars M and N to the points of emergence. The rays E X G are thus made to converge at F, which is called the *focus*, (meaning a *fire-place*,) because such a glass, when used to gather together into a point the quantity of solar rays which fall upon it, the heat so concentrated is found to be powerful enough to inflame combustible matters; it is, in fact, a *burning-glass;* and, in the language of opticians, it is a *lens.*

The effect is precisely similar when the rays proceed from a luminous point, as a candle at C. In this case, the rays fall up-

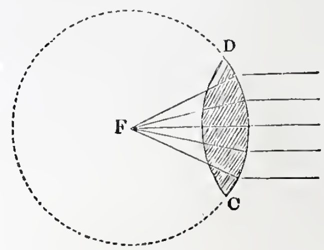



on the glass in a cone of diverging light, which, passing through the doubly convex glass, is made to converge to a focus F. Here, as before, the middle ray, or axis of the cone C D, is not bent, whereas all the other rays are bent more and more, in proportion as they fall upon the lens farther and farther from the centre D. It may, however, be here remarked, that the focus is, in this case, farther distant from the surface of the refracting medium than in the case of the parallel rays; and were we to examine the position of the focus in a case of a *converging* pencil of light, we would find it still nearer the surface of the lens than when the rays are moving parallel. Further—it is in accordance both with calculation and experiment, that the direction in which a pencil of rays falls upon a lens does not affect the result of the convergence to a focus, only the focus is *always* in the direction of the central ray of the luminous stream; it is at P, for instance, when the light issues at O, and at Z when the light issues at X.

What is called the principal focus of a lens, and by the distance of which from the glass we compare and classify lenses among themselves, is the point at which the sun's rays, or any parallel rays, are made by it to meet. This focus is therefore readily found by holding the glass in the solar beam, and noting at what distance behind it the luminous image of the sun has its least magnitude. As a remarkable coincidence, we find the following laws, which are easily remembered. If the lens A B be simply the segment of a sphere, the focus is exactly in the circumference. This, however, is only strictly true when the plane side is exposed to the luminous rays; if the convex side be exposed to the rays, as in the figure, the strict focus will be found to fall within the circumference of the sphere by a quantity equal to two-thirds of the thickness of the glass.




Again, should the lens be doubly convex, and the sides of equal curvature, the focus is equal to the radius—that is, would fall where the centre of the sphere would be, of which the surface of the lens is a portion. If the curvatures of the two sides be different, the law is somewhat more complicated: in this case we divide twice the product of the two radii of the spheres, of which, we may suppose, the surfaces of the lenses to be portions, by the sum of these radii, and the quotient is the focal length sought.*




* It is not consistent with our present purpose to enter into the mathematics of the refraction of light by lenses; but as the formulæ for finding the focal lengths of convex lenses are often required, we may here insert them for reference.

Let the radius of curvature of one surface .................................. $= R$.
Let the radius of curvature of the other surface .......................... $= R'$.
Let the distance of the source of light ........................................ $= d$.
Let the distance of the point of convergence of the rays from the lens ........................................ $= d'$.
Let the thickness of the lens ........................................ $= t$.
And let the focal length be called ........................................ $= F$.

1. *For parallel rays.*

(Such as those of the sun, which, in their passage to the earth, do not diverge the millionth part of an inch in a thousand miles, and may therefore, for all practical purposes, be reckoned parallel.)

Double-convex lenses of *equal* curvature have (as stated) $F = R$

Double-convex lenses of *unequal* curvature have (as stated) $F = \frac{2(R \times R')}{R + R'}$

Plano-convex lenses, { Plane surface exposed to the rays, $F = 2R$
Convex surface exposed to the rays $F = 2R - \frac{2}{3}t$ }

2. *For diverging rays.*

In equally double-convex lenses, ........................ $F = \frac{d \times R}{d - R}$

In unequally double-convex lenses, ...................... $F = \frac{2(R \times R') \times d}{d(R + R') - 2(R \times R')}$

In plano-convex lenses, ........................................ $F = \frac{d \times R}{d - 2R}$

3. *For converging rays.*

Equally double-convex lenses, ........................... $F = \frac{d' \times R}{d' + R}$

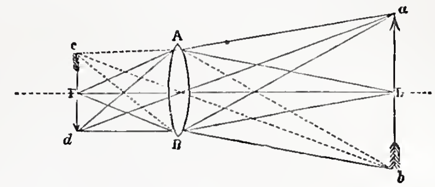
Double-convex lenses of unequal curvature, ......... $F = \frac{2(R \times R') \times d'}{d'(R + R') + 2(R \times R')}$

Plano-convex lens, ........................................ $F = \frac{2(d' \times R)}{d' - 2R}$

In connection with these formulæ, it may be proper to point out more

These facts lead to another which is easy to be borne in mind, and which is at once obvious without any process of reasoning. It is this: the greater the convexity of the lens, the smaller its focal length; that is to say, as the sphere diminishes—of which the surface of the lens is a portion—the focal distance likewise diminishes. It may also be remarked, that because the focal point of light passing through a lens is at the same distance from the centre of the lens, in whatever direction the light passes through, a surface placed to receive the image should be at precisely the same distance from the centre of the lens—it should, in fact, be concave, for otherwise the image will be less perfect towards its extremities, and *vice versa*. In practice, however, it is not found necessary to attend to this precaution generally; and, indeed, only in cases where the image is of very considerable extent, compared with the object from which it is obtained.*

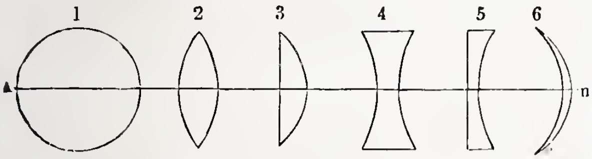
The manner in which images are formed by reflection and refraction has already been incidentally pointed out, in the case of mirrors, and in the preceding remarks; but there are still some instructive properties connected with their formation by lenses, which it may be interesting briefly to consider. If L be a luminous point of the object, *ab*, that point will send a cone of




rays to the lens AB, all of which, it can be shown, will meet in F, the focus of the lens. Similarly, a cone of rays projected from *a*, will be brought to a focus at *d*, on the axial ray *a d;* and, in like manner, a cone of rays from *b* will come to a focus in *c*, on the axial ray from *b c*. But every point of the object *a b* projects its cone of rays to the lens by which they are made to converge to their respective points in the line *c d*, upon which is therefore formed an image of the object. This image might be received upon a screen placed in the line of foci; and to an eye placed in a proper situation to observe it, the image will appear very distinct, and having all its natural colours; but obviously *inverted* in consequence of the crossing of the rays. It may also be observed, that the size of the image, for the same lens, is always proportioned to the respective distances of the object and the screen from the centre of the lens. If *c d* be the object, and *a b* the place of the screen, the image will be magnified. It will also be most distinct when the object and the screen are each placed in the *conjugate foci* of the lens,—meaning by *conjugate foci*, two points of distance on the opposite sides of the lens, such that when either becomes the point of radiant light, the other is the focus of such light. It is, indeed, when we have made this adjustment, that we obtain the full power of a burning-glass: in this case, the sun and his image are in the conjugate foci of the lens; and respectively just as distant from the centre of the lens as the object surpasses the image in magnitude. Conversely, had we a screen of sufficient size hung up in distant space, and a bright enough object of the tenth of an inch diameter, we might adjust our lens to form an image of it upon the screen as broad as the solar disc itself.

The applications of these principles are very numerous. A convex lens, like that described, fixed to admit light into a darkened chamber, constitutes the *camera obscura*. The inverted images of external objects being received upon a white board, ground glass, or paper screen. In the simple telescope, the lens is placed at the extremity of a tube of sufficient length to allow the image to be formed within it, and the observer looks from the other end at this image. The eye acts upon the same principle as the camera obscura, but with a power of self-adjustment not yet well understood. To state the difficulty,—were the eye an ordinary lens, having an invariable focus, our range of vision would manifestly be very narrow: for, bearing in mind that the condition of distinct vision is the formation of the image *upon* the retina, it is plain that an eye, adjusted for seeing distant objects, would be useless for near ones; and eyes fitted for near objects would be blind to those that were remote. When, however, we observe a distant landscape, and successively notice nearer and nearer objects, till, finally, we cast the eyes upon the page of a book only six inches distant, we have an illustration of the remarkable power of adjustment in the visual organs. All objects give off rays, having their respective degrees of divergence, and require in the optical instrument, through which they are observed, successive and corresponding alteration of the focus. This is accomplished in the telescope by alteration of the position of the glasses, which are placed in slides to admit of such adjustment. But the eye has no such perceptible means of adjustment, yet accommodates itself to the various distances at which objects happen to be placed without any conscious effort on our part. The mechanism by which this intuitive accommodation is accomplished, is not determined. The result has been supposed to be brought about by an alteration in the

precisely the meaning of the technical names by which lenses are distinguished. Sections of the principal kinds are here shown, and if these be




supposed to revolve round the axis A B, each will produce the particular lens of which it is the section.

1 Is the *spherical* lens: it is a simple sphere, which, if of glass, whose refracting index is 1·5, its focal distance will be half an inch for parallel rays. If it be tabasheer, whose refractive index is 1·11145, the focal distance is four feet from the lens; whereas in a spherical lens of zircon, whose refractive index is 2, the focal point coincides with the surface. To find the focal distance of such a lens from its centre, "divide the index of refraction of the material of which it is composed by twice its excess above unity"—the quotient is the focal distance expressed in radii of the sphere.

2 Is the *double-convex* lens; and 3 the *plano-convex* lens, already described; 4 is the figure of a *double-concave* lens. Both its surfaces are concave; its refractive power is, therefore, to produce, upon rays passing through it, an opposite effect to that of the double-convex lens; and may be so connected with a double-convex lens as to restore rays refracted by it to their previous direction. Its *negative focus* is found by the formulæ given for finding the focal length of the double-convex lens.

5 Is the figure of a *plano-concave* lens. It is merely a half of the double-concave lens, and its negative focus is found by the formulæ given for the plano-convex lens.

6 Is the figure of a lens called a *meniscus*, because it resembles the crescent moon. It has one surface concave, and the other convex, and these curves meet if continued. Its effect upon rays transmitted through it, is precisely the same as that of convex and concave lenses of the same focal lengths. It must always, however, have a positive focus, since the exterior curve has greater curvature than the interior one; in fact, for parallel rays, its formula is

$$F = \frac{2(R \times R')}{R - R'}$$

and for converging and diverging rays, its formula is

$$F = \frac{(R \times R') \times 2d}{d(R - R') + 2(R \times R')}$$

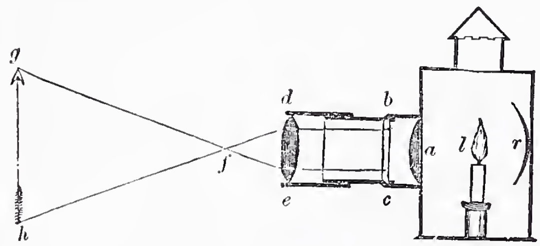
The meniscus is sometimes modified into what is termed the *meniscus-divergent*, which has similar surfaces; but their curves do not meet, although produced. Its negative focus may be found by the formulæ for the meniscus.

* This is the defect usually called *spherical aberration*, and is rendered very obvious in lenses of considerable curvature, on holding a screen of ground glass near the focus of the central rays: a picture of the object whose reflected rays pass through the lens is formed upon the screen, very vivid in the centre, but less and less distinctly defined towards the edges; and conversely on moving the screen a little back, the marginal portion of the picture becomes more vivid, and the central portion loses its distinctness. In the eye this evil is averted by the substance of the lens increasing in density from its margin to the axis; but as this cannot be imitated in glass lenses, it is usually attempted to be remedied in practice by combinations of lenses. By means of the *meniscus*, for instance, the spherical aberration may be reduced to an insensible quantity, if the convex surface be turned towards the object. Hyperbolic lenses have also been proposed, but the difficulty of constructing them has hitherto prevented their adoption.

form of the whole eye by the action of its muscles. Sir D. Brewster, however, supposed that the position of the crystalline lens only is altered, and that this alteration is effected by the contractile tissue which determines the movements of the iris and size of the pupil.

It is hardly necessary to state, that this adjusting power has a limit: the fact is matter of universal experience. At less distances than five inches, the rays, from small objects, are so divergent that their focal point falls behind the retina in most persons, and indistinct vision is the consequence. The *defect of near-sightedness* is, indeed, so great in some instances as to offer a marked exception to this limit, and arises from the refractive power of the lens of the eye being so great, that all rays which do not diverge rapidly are brought to a focus before they reach the retina. This explains the assistance which such persons, obnoxious to this imperfection, derive from concave glasses which cause the rays which pass through them to diverge before they fall upon the eye, and thereby counteract, to a certain extent, its refracting influence. *Long-sightedness* is the contrary defect: persons affected by it, are unable distinctly to see near objects owing to the weak refracting power of the eye. This is the infirmity of advanced life, and is remedied by convex glasses which give the rays a greater or less degree of convergence before they pass into the eye.

Several other instruments might be named in connexion with the law of refraction of light. Of these, the magic lantern is an example. This consists of a powerful lamp, *l*, the light of which




is concentrated by the reflector *r*, upon the lens *a*. The only use of this lens is to throw the light in a proper direction upon a transparent picture contained in a slide, inserted at *b c*. This picture is painted with bright transparent colours upon a thin plate of glass. The figures of the picture being strongly illuminated, the light proceeds in a strong diverging beam to the lens *d e*, which has its focus at *f*. After this point, it continues to diverge in the directions *f g*, and *f h*, until it is received upon a screen placed for the reception of the image. It is thus manifest, that the size of the image will depend on the distance of the screen from the focal point *f*; but bearing in mind that the intensity of light diminishes as the square of the distance, the image becomes less and less bright as the distance of the screen is increased. The tube in which the lens *d e* is placed, is also made moveable for the purpose of adjustment, as in the case of the telescope.

The exhibitions of *phantasmagoria* which rarely fail to delight and astonish the beholders, are nothing more than well managed applications of the apparatus described. The lantern for purposes of this sort has some contrivance by which it is made to recede and advance, and is manœuvred on one side of a thin transparent screen, while the spectators, not aware of the existence of such a screen, are sitting on the other side. No light is allowed to pass except what passes through the picture, so that the image appears as it were in the air; and by a dexterous management of the apparatus is made apparently to advance and recede; now expanding and advancing, seemingly over the heads of the spectators, and again contracting and seeming to recede, until lost in the distance.

A very slight modification of the magic lantern converts it into a *lucern microscope*, and this, when the light is supplied by a ball of lime placed in the flame of a small jet of oxygen and hydrogen gas, constitutes the *oxy-hydrogen microscope*. When the sun's light is used to illuminate the object, the instrument takes the name of the *solar microscope*. The chief distinction between these instruments (rather instrument), consists in the greater refracting power of the lenses.

"The magnifying power of a lens may be determined by the limit of distinct vision for minute objects which is generally about five inches, divided by the focal length of the lens. This refers to the linear magnifying power, and only to the number of times that the image is magnified in length. The superficial power being obtained by squaring its linear (that is by multiplying the linear power into itself), and the result shows the number of times the whole surface appears to be magnified." This rule is exemplified in the following table:—

| Focal length of lenses in inches. | Magnifying Power. | |
|---|---|---|
| | Linear. | Superficial. |
| 5 | $5 \div 5 = 1$ | $1 \times 1 = 1$ |
| 4 | $5 \div 4 = 1·25$ | $1·25 \times 1·25 = 1·5625$ |
| 3 | $5 \div 3 = 1·66$ | $1·66 \times 1·66 = 2·7556$ |
| 2 | $5 \div 2 = 2·5$ | $2·5 \times 2·5 = 6·25$ |
| 1 | $5 \div 1 = 5$ | $5 \times 5 = 25$ |
| $\frac{1}{10}$ | $5 \div \frac{1}{10} = 50$ | $50 \times 50 = 250$ |
| $\frac{1}{20}$ | $5 \div \frac{1}{20} = 100$ | $100 \times 100 = 1000$ |

# CHEMISTRY OF INORGANIC NATURE.

## CHAPTER II.

### OF THE CHEMICAL PROPERTIES OF THE ATMOSPHERE.

It has already been observed, that the mass of atmospheric air enveloping our earth is equal to the weight of a hollow sphere of quicksilver, thirty inches thick, and covering the whole surface of the globe. Now, as air is 3425·9 times lighter than mercury, it follows, that if its density in the higher regions were as great as at the surface of the earth, the height of the atmosphere above the surface of the earth would be only 1·64 miles. But it is well known that the density of the air diminishes, as we ascend, and if we reckon the height in an arithmetical progression, the diminution of density will go on in a geometrical progression.

It is affirmed that air-pumps have been constructed so excellent that they were capable of rarefying air 1000 times. Now, at the height of 42 miles, this would be the rarity of the atmosphere; so that if a barometer were elevated 42 miles above the surface of the earth, the height of the mercury in it would be rather less than $\frac{1}{1000}$th of an inch.

Kepler pointed out a very ingenious way of determining at what height the atmosphere ceases sensibly to refract light. Twilight terminates when the depression of the sun below the horizon amounts to 18°. Now, it is easy to deduce from this, that when the height of the atmosphere exceeds 49 miles, it ceases to refract light. This of course is the height of the atmosphere, as far as utility is concerned. But it is probable that it extends farther than this, and there is no difficulty in assigning its absolute limit. The higher parts of the atmosphere are carried round the earth in 23 hours and 26 minutes, by the rotation of the earth about its axis. Now these parts would be projected from the earth, and would leave it altogether, if their centrifugal force were greater than their gravitation to the centre. But the centrifugal force varies directly as the distance, while gravitation varies as the square of the distance. It can be shown that these forces become equal at the distance of 6·6 radii of the earth, or about 26,000 miles. Hence we are sure that no part of the atmosphere can be farther from the surface of the earth than 26,000 miles.

The mean height of the barometer, which measures the quantity of atmospheric air at the surface of the sea, and the temperature of 32°, is 29·9546 inches; so that, at the temperature of 60°, the mean height of the barometer at the level of the sea is 29·9869 inches, or only 0·013 inch less than 30 inches.

The absolute weight of 100 cubic inches of dry and pure air at the temperature of 32°, is 32·79 grains.

When we continue to observe a barometer in the same place, everybody knows that it does not remain stationary; but rises and falls. These changes are connected with the winds; accordingly, in the torrid zone where the winds are pretty regular, the rise and fall are trifling, amounting only to a few tenths of an inch. At Madras, for example, (north latitude 13° 4′ 8″.513), the variation is only 9·6 inches, and the greatest annual range ever observed in that place, was 0·664 inches, and the smallest 0·462 inches.

As we advance northward or southward from the equator, the range increases. In Glasgow, it amounts to 2·95 inches, and at St Petersburgh, it exceeds 3 inches.

It has been observed, that there are two periods of every day when the barometer is highest, and two corresponding periods in which it is lowest. These maximums and minimums are observed in all parts of the earth, nearly at the same time of the day, showing that they originate in tides of the atmosphere, occasioned by the action of the sun. The barometer is highest of all between nine and ten in the morning. It has another smaller maximum between ten and eleven at night. Its lowest points are between four and five in the evening, and four and five in the morning. These oscillations extend from the equator to latitude 64° 8′, beyond which point they have not yet been looked for: but they diminish in amount as the latitude increases.

The mean temperature of the air at the level of the sea is highest at the equator, and gradually sinks as we advance toward the poles. The mean temperature at the equator is 81°·5; in Antigua, 78·11; in latitude 45°, it is 56°. In Paris, (lat. 48° 49′) the mean temperature is 51°·48; in London, it is 50° or 51°; in Plymouth, 52°·08; in Glasgow 47°·75; in Edinburgh 47°·7. In Geneva, about 1640 feet above the level of the sea, and in latitude 46°20′, the mean temperature is 49°·55. In Victoria harbour, N. lat. 70°, it is 0°·82. The temperature at half-past nine in the morning is nearly the mean of the day.

The range of the thermometer increases with the latitude, and with the height above the sea

| | | | |
|---|---|---|---|
| At Poona it is | 53°·4 or from | 40°·5 | to 93°·9. |
| Paris, | 76·2 | 23·4 | to 99·6. |
| Berne, | 119·25 | —24 | to 95·25. |
| St Petersburgh, | 127·1 | —35·7 | to 91·4. |
| Victoria harbour, lat. 70° | 130 | 60 | to 70. |

But in Great Britain this rule does not hold,—our heat and cold being both checked by the proximity of the sea. The greatest range of the thermometer in

London is 93° namely from 0° to 93°
Glasgow is 84 . . . . 0 to 84.

The atmosphere consists essentially of two distinct gaseous bodies, namely oxygen and azote. But besides these, it always contains a sensible quantity of carbonic acid gas; nor is it ever free, (at least in Europe,) from the vapour of water mixed with it in the gaseous state. Doubtless it contains also minute quantities of every gaseous body and of every vapour which is thrown into it from the surface of the earth, though (except in particular circumstances,) the amount of all of them besides the four first mentioned, is too small to be appreciable by our methods of investigation.

100 volumes of atmospheric air (supposing it freed from carbonic acid and moisture,) consist of 80 volumes of azotic, and 20 volumes of oxygen gases. These proportions, being constant on every part of the surface of the earth, have led to the notion that the oxygen and azote in the atmosphere are in a state of combination, and not merely mixed; but this by no means follows. For the supply of atmospherical air is so vast, that if we were to suppose a thousand millions of animals constantly breathing it for six thousand years, and converting oxygen into carbonic acid gas, and if we were to double this consumption of oxygen, for the fires that are continually burning in all parts of the earth, it would not make an appreciable alteration in the ratio of oxygen to azote.

1. Oxygen is a gaseous body which is invisible and destitute of colour, taste, and smell. Its specific gravity is 1·1111, that of air being 1. One hundred cubic inches of it at 32° weigh 36·4330 grains. It is essential to the existence of all animals, being absorbed in the lungs, and partly converted into carbonic acid. When animals are made to breathe a determinate quantity of common air, the oxygen gas in it is gradually diminished, and converted into carbonic acid; and when this change has proceeded a certain length, the animal dies of suffocation. The same thing happens when the animal is made to breathe oxygen gas instead of air. But in oxygen gas, he lives nearly twenty times as long as in the same bulk of atmospherical air.

The oxygen of the air also supports combustion. The common combustibles are chiefly compounds, carbon and hydrogen. During combustion, they combine with the oxygen of the atmosphere, and are converted into carbonic acid and water. Thus, combustion and the breathing of animals constantly diminish the oxygen of the air, and in process of time would no doubt absorb the whole, were it not that new oxygen is constantly thrown into the atmosphere by the vegetation of plants. Thus, the functions of animals and vegetables counteract each other. Animals are constantly diminishing the oxygen, and increasing the quantity of carbonic acid in the atmosphere. Plants, on the other hand, are constantly absorbing the carbonic acid thus formed, decomposing it, retaining the carbon and giving out the oxygen. These two opposite processes no doubt counterbalance each other, and thus the oxygen of the air does not diminish, nor the carbonic acid increase.

2. The *azotic* or *nitrogen* gas constitutes four-fifths of atmospheric air. Like oxygen it is colourless, invisible, and destitute of taste and smell. Its specific gravity is 0·9722, that of air being 1. One hundred cubic inches of it at 32° weigh 31·8790 grains. It is not sensibly absorbed by animals nor by plants, nor does it support combustion. No animal can breathe it without suffocation; but it qualifies the stimulating property of oxygen gas. When an animal breathes oxygen gas, the heat is increased, and the circulation accelerated, and a feverish state comes on, which speedily destroys the animal. The admixture of azote prevents these injurious effects, and preserves the animal in a state of health.

Azote constitutes a part of the system both of animals and vegetables. In animals the azote which they contain is derived from the food which they eat. It is not so easy to see the origin of it in vegetables. But there can be no doubt that the azote of the atmosphere is employed in the formation of nitric acid,* and that this nitric acid, after it has been generated, is in various processes converted into ammonia.† It is probably from one or other of these two sources, that the vegetables derive the azote which they contain. These, in their turn, supply animals with that necessary article; and doubtless, during the putrefaction of animal substances, the azote thus absorbed is again given out, and thus its quantity in atmospherical air remains unaltered.

3. Carbonic acid gas, the third constituent of the atmosphere, constitutes rather less than $\frac{1}{1000}$th of its volume. It is colourless and invisible; but neither destitute of taste nor smell. Its taste is decidedly sour, and it impresses on the nostrils that sensation which is observed when a bottle of brisk ale, or of champaign just drawn, is applied to them. Its specific gravity is 1·5277, or it is rather more than $1\frac{1}{2}$ times that of common air. One hundred cubic inches of it at the temperature of 32° weigh 49·9780 grains. No animal can breathe this gas, and it immediately extinguishes a candle. Indeed a candle will not burn in a mixture of nine parts of air, and one part of carbonic acid; so that the atmosphere would become unfit for the respiration of animals, and the combustion of fuel, if it contained the tenth part of its bulk of carbonic acid gas.

Carbonic acid gas is constantly forming by the processes of breathing and combustion; yet its quantity never undergoes any sensible increase. Every individual, at an average, by breathing, throws 272 cubic feet of carbonic acid gas into the atmosphere in 24 hours. If we suppose the population of Glasgow to be 350,000, the quantity of carbonic acid gas, thrown daily into the atmosphere by 350,000 human beings, would be 95,200,000 cubic feet. If we admit the other animals, horses, cows, dogs, cats, birds, &c., to amount to $\frac{1}{10}$th of 350,000, they would produce about 10,800,000 cubic feet more; ‡ so that the whole carbonic acid thrown into the atmosphere in Glasgow by breathing, in 24 hours, must amount to 106,000,000 cubic feet.

If we suppose the consumption of coals in Glasgow and the neighbourhood to amount daily to 3000 tons, this will produce 1,438,013 cubic feet of carbonic acid gas. Thus, the whole of

* Composed of nitrogen and oxygen.
† Composed of nitrogen and hydrogen.
‡ This estimate must be greatly under the truth. A cow in 24 hours throws into the atmosphere, by breathing, five times as much carbonic acid as a man does.

that gas thrown daily into the atmosphere in Glasgow, cannot be less than 120,000,000 cubic feet.

Every volume of carbonic acid gas produced renders five volumes of air unfit for respiration. Hence, in 24 hours, 439,385,100 cubic feet of air are rendered unfit for respiration, or in fact poisonous.

Now, a base of four square miles, with a height of 100 feet, contains 44,605,000,000 cubic feet, of which 8,921,000,000 are oxygen gas. Consequently, in little more than 117 days, the whole oxygen in that space would be converted into carbonic acid gas, and every living being in Glasgow and its environs would be destroyed. Yet if we examine the atmosphere in Glasgow or its neighbourhood, we find it always to contain the usual volume of oxygen gas, and the proportion of carbonic acid gas never exceeds $\frac{1}{1000}$th of the volume of the atmosphere.

This is a most important circumstance, upon which the healthiness of cities entirely depends. It is owing to a property which gases possess. Every gas is composed of particles which repel each other; but the particles of one gas do not repel those of another. The particles of oxygen gas repel the particles of oxygen gas; and in like manner the particles of carbonic acid gas repel those of carbonic acid gas; but a particle of oxygen gas does not repel a particle of carbonic acid gas. The consequence of this property is, that every gas diffuses itself equably through the whole atmosphere. The carbonic acid gas, formed in Glasgow and its neighbourhood, does not remain in Glasgow, but diffuses itself equably through the whole atmosphere; and the atmosphere is so vast, that this quantity of carbonic acid gas, and millions of millions more, from other towns and cities, have no sensible effect in increasing the volume of that gas; its quantity is also kept down by its absorption and decomposition by plants, which replace the oxygen as it is withdrawn, and prevent the ratios of the constituents of the atmosphere from changing much.

4. The fourth constituent of the atmosphere is the vapour of water. It varies much more in its proportions than any of the other constituents. It is well known that water evaporates at every temperature from zero to the boiling point, and that the rate of evaporation increases with the temperature. This evaporation is entirely confined to the surface, and is therefore proportional to the surface. It is promoted by wind, and increased by heat. If the quantity evaporated per minute from a given surface of water, at the temperature of 18°·5, be represented by 2, the increase of evaporation as the temperature augments is shown by the following table :—

| Temp. | Rate of evaporation. | Temp. | Rate of evaporation. |
|---|---|---|---|
| 18°·5 | 2 | 125° | 64 |
| 38 | 4 | 150 | 128 |
| 58 | 8 | 180 | 256 |
| 79·5 | 16 | 212 | 512 |
| 100 | 32 | | |

So that if we fill a pan with water, and raise its temperature to 100°, it will take 16 times as long to evaporate, as it would do if heated to 212°.

When water evaporates, it is converted into an elastic fluid, invisible likewise, and destitute both of taste and smell. But its specific gravity and its elasticity increase with the temperature. At 212° its elasticity is the same as that of common air,—hence the reason why water boils at that temperature. It is called *steam* at that temperature, and its specific gravity is 0·625, that of air being 1. If we force the particles of steam nearer each other than when they possess just the elasticity of the atmosphere, they give out heat, and are partly or wholly converted into water, according to the degree of pressure. The elasticity of vapour diminishes with the temperature. This elasticity is measured by height, which its pressure produces on a column of mercury in a barometrical tube. At 212° this height amounts to 30 inches; at 180° it amounts to 15 inches; at 150° to 7·5 inches; at 125° to 3·75 inches; at 100° to 1.875 inches, and so on.

The quantity of vapour capable of existing in the atmosphere depends upon the temperature. How much is present at any time is easily ascertained by determining the temperature at which moisture is condensed, upon the external surface of a glass tumbler exposed to the air. If moisture be condensed on the tumbler when of the same temperature with the air, then the atmosphere contains as much moisture as it can contain at that temperature. Such is the case sometimes in this country, and it is indicated by the circumstance, that when wet clothes are hung out to dry, they retain their moisture because the water with which they are wet cannot evaporate. Should the tumbler remain dry, as will generally be the case, we must cool it by filling it with water colder than the air. This, in summer, is easily got from wells or deep springs. In winter, we must cool the water with ice, or by a mixture of snow and salt. By allowing the cooled tumbler to heat, till water just ceases to be condensed on it, and noting the temperature, we have the point indicating the elasticity of the vapour of water in the atmosphere.

Dr Dalton drew up, many years ago, a table showing this elasticity at every temperature. The following table shows a few of these elasticities.

| Temp. | Force of vap. in in. of mercury. | Temp. | Force of vap. in in. of mercury. |
|---|---|---|---|
| 32° | 0·2 | 60 | 0·52 |
| 40 | 0·26 | 70 | 0·726 |
| 50 | 0·36 | 80 | 1·012 |

Many experiments have been made in this way in different places, to determine the quantity of vapour in the atmosphere in different parts of the earth. In Glasgow the greatest quantity of vapour exists in the atmosphere, in the month of August. The mean dew point (as the point at which moisture begins to condense on the tumbler is called,) is 50°, indicating an elasticity of 0·3766 inch. This amounts to about $\frac{1}{80}$th of the volume of the atmosphere. The smallest quanity is usually in the month of February, when the dew point is between 36° and 37°, indicating an elasticity of vapour amounting to 0·2314 inch: this amounts to nearly $\frac{1}{130}$th of the volume of the atmosphere. But though the volume of vapour in August be much greater than in February, the atmosphere is drier in the former month than the latter because the dew point, 50°, is at a greater distance from the mean temperature of the month, than 36° is below the mean temperature of February.

In some parts of the west coast of Africa, and in India, the atmosphere seems sometimes to contain no vapour, or very little. The mean dew point in Antigua, during July, August, and September, is 74°·43. The highest dew point observed by Col. Sykes, in the Deccan, was 76°. The mean dew point was 60°·74, and the mean temperature 78°·5. Thus, the air in India, though containing $\frac{1}{80}$ of its volume of vapour, is much denser than in Glasgow.

## ANATOMY AND PHYSIOLOGY.

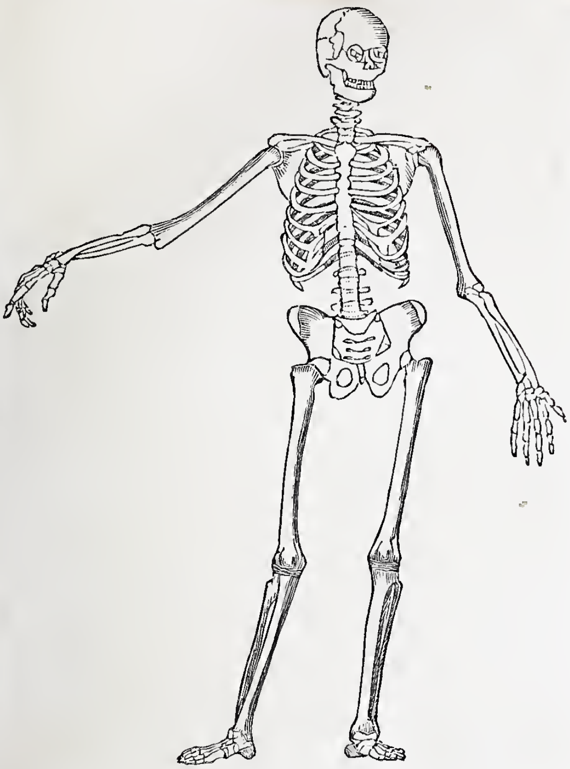
### CHAPTER X.

#### THE SKELETON.

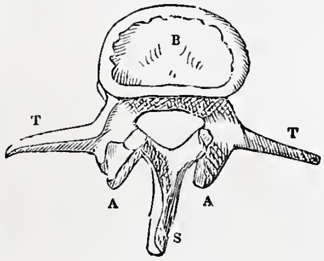
The Skeleton consists of the head, the trunk, and the extremities. No explanation is needed to define the limits of the head. The trunk is composed of the spine, the ribs, the breast-bone, and the pelvis; supporting the head upon its upper end, and resting its lower end on the heads of the thigh-bones. The extremities are four—two superior, commonly called in man, the arms; and two inferior, commonly called the legs; but, in strict anatomical language, the word leg is applied only to the part below the knee, the part above being always spoken of as the thigh; and only the part above the elbow is called the arm, the part below being the fore-arm. We shall now examine these parts in succession more minutely.

The *Spine* is the central column, resting on the pelvis and thigh-bones, and supporting the chest, the head, and the superior extremities. It is about one-third of the length of the whole body; so that in a man who stands six feet high, the spine will be found about two feet long. It consists of twenty-four pieces, or *vertebræ*, named from the Latin word *vertere*, to turn, on account of their mobility. The largest is placed below, and they diminish gradually to near the top. Each vertebra is an irregular

bone in its structure, (see page 268,) and consists of a *body* and *processes;* the word process in anatomy signifying a projection



or prominence. The body of each vertebra is of the nature of a short bone, spongy in its texture, and very light. It is semicircular, or nearly so, being convex in front, and is flat above and below, where it supports and rests upon its neighbours. In the accompanying cut, B represents the body of the vertebra, with its upper flat surface turned toward the reader. From the back of the body, the arch of the vertebra is seen to spring, enclosing a space which is occupied by the spinal marrow. A couple of articular processes, A A, are seen, which receive a corresponding pair from the vertebra above, and two, similar to




these, are sent downward, to articulate with the one next below. Then, to serve as levers, for the purpose of bending and turning the spine, we have two transverse processes, T T, passing out on each side, and the spinous process, S, passing backward. These spinous processes form the chain of projections felt under the skin, which give the name to the whole column. The four-and-twenty vertebræ are joined together so as to allow of a little motion, and but a little, at any one joint, in order that the spinal marrow which passes down through the canal formed by the apposition of the different rings, may not be injured by too sudden a twist; but that the curves which it is obliged to form, in the various motions of the body, may be very gradual.

Even when at rest, the spine is not straight, but curved in three different places. First, it curves forward, where it rests on the pelvis, that it may not be exposed to too rough a shock, when we begin to move, from being in a state of rest. Secondly, it curves backward, in the region of the back, to increase the capacity of the chest, in which the heart and lungs are to be lodged. Thirdly, it curves forward again in the neck, in order to bring the weight of the head, which rests on it, over the point of support between the feet. Three regions are distinguished in the spine—the first, the cervical, or that of the neck, consisting of seven vertebræ; the second, or that of the back, consisting of twelve; and the third, or that of the loins, consisting of five. The vertebræ of the loins are the most moveable: it is here that the turning and bending of the trunk chiefly takes place, and, consequently, it is to this region that injuries are most apt to occur. Those of the neck are also very moveable, in order to allow of the head being turned in every direction, principally, it would seem, to extend, as much as possible, the sphere of vision.

To the twelve vertebræ of the back the ribs are attached—twelve on each side, in order to form the chest. On this account, they admit of but little motion on one another, because they, with the ribs and breast-bone, are to work together, as constituting, in a great measure, a single organ.

The *ribs* are long curved bones, convex externally, and concave internally. They get gradually longer from the first to the seventh, and from that shorter again to the twelfth. The ten upper ribs are connected to the breast-bone in front, by means of thin cartilages; which arrangement, it has been already remarked, gives elasticity to the walls of the chest. The lowest two, not being attached in front, are called the floating ribs. The heads of the ribs behind are connected to the vertebræ by a kind of hinge joint, which allows each rib to move up and down in the action of breathing. Each rib passes from its attachment, downward, outward, and forward; so that when lifted up by the muscles of inspiration, it at the same time is carried outward, and so enlarges, in both directions, the capacity of the chest.

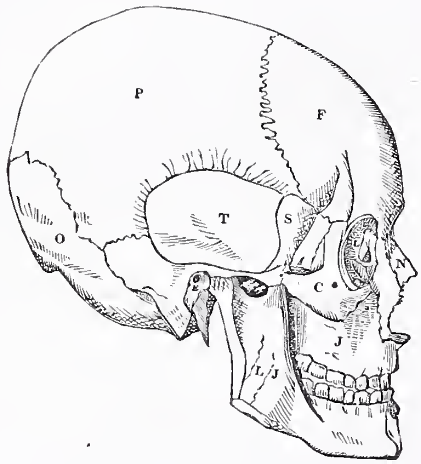
The *breast-bone* is about seven inches long, about two broad above, and one below, and ends in a moveable point formed of cartilage. It is smooth and convex in front, gives the prominence to the fore-part of the chest, and projects conspicuously in some individuals, who are thence commonly called "pigeon-breasted." It has the cartilages of the ribs inserted into its edges; it has a hollow in its upper part to make room for the wind-pipe to pass down behind it, and to its two upper corners the two collar-bones are attached.

The *Chest*, viewed as a whole, is conical—the apex of the cone being above, and the base below; the aperture above is small, measuring about four inches across, and two from before backward, allowing the wind-pipe and gullet, and the great veins of the arms and head to pass down, and their arteries to pass up. The inferior opening of the chest is large, and is filled by a muscle named the *diaphragm*, a Greek word, which literally means *the partition;* because it separates the belly from the chest, forming a roof for the one and a floor for the other. The chest is considerably deeper behind than in front, and the edges of the cartilages of the ribs can be felt, and, in a thin person, seen passing upward from the flanks, and meeting at an angle with the breast-bone, leaving a hollow between them, which is known as the pit of the stomach.

The *Pelvis* is so named because it is somewhat like a basin, only it has a wide aperture in the bottom, through which the canals from the bowels and the bladder, and in the female from the womb, make their exit. It consists of three distinct parts, the two haunch-bones, and the rump-bone. The last part sometimes receives the name of the false vertebræ—for in the young subject it consists of five pieces, which are real vertebræ—but in the adult these are firmly united into one, convex behind, and concave in front. It is of a triangular form, the base above, and the point below; and is terminated by two little pieces which do not make any projection externally, but are the same as those which, in greater number, constitute the tails of the lower animals. They are all that man possesses for a tail, or ever did possess,—all that Lord Monboddo has written to the contrary notwithstanding. The portions of the pelvis which form its sides are of a very irregular figure, expanded above on each side to form the projections of the haunches, narrow where they meet in front to form the part called the share-bone; having two knobs below, on which we sit, and two sockets below and towards the front, for receiving the heads of the thigh-bones. From the structure of the pelvis it will be understood that it forms nearly a circle, possessing the strength of the double arch. The upper part of the arch has its abutments resting on the heads of the thigh-bones, and supports the spine upon its key-stone; while the reversed arch below binds the abutments together, and prevents their separation. The pelvis has another use, in forming the floor to the cavity of the belly, and so assisting to support its

contents, and yet another in giving origin to the powerful muscles which move the lower limbs.

The *Head* is placed upon the end of the spinal column, in order that the brain which is contained in it may be connected with the spinal marrow; and upon its upper end, that the eyes which are set in it may enjoy the widest possible range. It consists of two parts, the *cranium* and the *face;* the former for containing the brain; the latter for the organs of sight, smell, and taste. The *cranium* is very nearly of the shape of an egg, the larger end being backward, and the smaller one forward; presenting thus the characters, and having the strength of a double dome. The upper dome is however stronger than the lower one; and hence we find that when a man falls from a height on his head, the fracture is most frequently not at the part struck, but at the base, where it is completely out of the reach of the surgeon. The *face* cannot be compared to any known regular figure; it is excavated by several cavities, one large one for the mouth, another of considerable size for the nose, and two smaller pyramidal ones for the eyes, called the orbits. The number of bones in the head is twenty-two.




F. Frontal bone. P. Parietal bone. T. Temporal bone.
O. Occipital bone. S. Sphenoid bone. C. Cheek-bone.
J. Upper jaw-bone. L. J. Lower jaw-bone. N. Nasal bone.
L. Lachrymal bone. E. Hole leading into ear.

The *Cranium* or brain-case is composed of eight bones, which are mostly of a flattened form, convex externally, and concave internally. The *frontal* bone forms the forehead, and the roofs of the orbits; the *occipital* bone forms the back and under part of the head, and in this bone is the large hole through which the spinal marrow passes down from the brain. The two *parietal* bones meet in the middle above, and form the upper and lateral parts of the head; in the centre of each is a protuberance giving the greatest breadth to the head, rather farther back than its middle. The *temporal* bones are named from the Latin word *tempus*, signifying time, because on the hair covering them, the traces of time are first manifested. They are placed one on each side, occupying the inferior lateral parts of the cranium, and extending into its base. In each is seen the funnel-shaped opening which admits the waves of the air to the drum of the ear, called the external auditory canal, to the edges of which the external ear is appended. The hard part of each, extending into the base of the cranium, contains the essential part of the organ of hearing. The two remaining bones are placed at the base of the cranium, and belong equally to it and to the face. The *æthmoid* or sieve-like bone is so named, on account of its upper plate being perforated with forty or fifty holes, through which the twigs of the olfactory nerves pass into the nose. A small part of it forms a portion of the inner boundary of the orbit, but this cannot be seen in the engraving. The *sphenoid*, or wedge-like bone is so named, not from any similarity to a wedge in shape, but from its being wedged in among so many other bones; for it is united to the other seven bones of the cranium, and to five of the face, all of which it in a great measure serves to bind together.

The vault of the cranium is smooth and regular, where it forms a roof for the protection of the brain; the floor of it is divided into six pits or deep hollows, for containing the different lobes of the brain. Numerous holes exist in the base of the cranium, for the entrance of the nourishing arteries of the brain, for the exit of its veins, and for the passage of numerous nerves which are to connect the brain with the organs of the senses, and with the other parts of the body.

The *Face* consists of fourteen bones; six pair, and two single ones. The two *upper jaw-bones* form the principal part of the face. They meet in the middle line, forming the arch in which the upper row of teeth are set, and extend backward, forming the principal part of the roof of the mouth. A process runs up from each, separating the cavity of the nose from that of the orbit. In order that the face may be lighter, the body of the maxillary bone is not solid, but excavated,—the cavity communicating with the nose, as will be seen in the description of that organ. The roof of the mouth is completed by the two *palate-bones.* The firm part of the nose, from its roof to its bridge, is formed of two small pieces, meeting in the middle, called the *nasal bones.* These are liable to be broken, or knocked in, by a blow, an injury which occasions great disfigurement. The opening of the nose in front is seen in the skull to be of an oval figure, bounded by the two nasal and the two upper jaw-bones. Bounding the lower and outer parts of the orbits are the two *malar* or *cheek-bones*, making the prominences on the sides of the face, which are so marked in the races of Celtic origin. At the inner sides of the orbits are two little bones of the size and shape of the finger nail, called the *lachrymal bones*, because they form the chief part of the canals through which the tears find their way into the nose. Forming the partition of the nose, is a bone resembling a ploughshare in shape, whence its Latin name *vomer;* and in each side, within the nose, is a *spongy bone*, for the purpose of extending the olfactory surface. Finally, the *lower jaw* is a single bone, its dental arch equalling in size that formed by the upper jaw-bones, and containing as many teeth. The forepart of this bone is the chin, extending back from which, and gradually separating from each other, are its sides, which terminate at the angles, and from the angles the branches rise nearly perpendicularly upward, to be attached by moveable joints to the sockets in the two temporal bones.

Though composed of so many pieces, the whole head moves as one mass on the top of the spine; and the only motion that takes place between its parts, is the opening and closing of the mouth. This is done by the lower jaw dropping and being again lifted, while the upper jaw remains unmoved. This arrangement holds good in all beasts and birds; it is only when we descend to the reptiles and fishes, that we find both jaws moving, as in the crocodile and the shark.

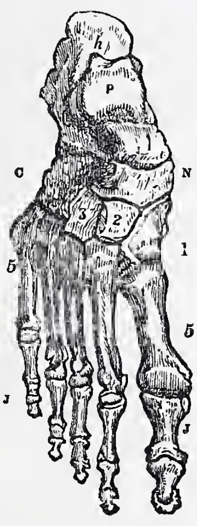
The *orbits* are two cavities placed in the face, for containing the eyes. Each orbit is of a conical figure, the apex being behind, where the optic nerve enters it, and the base being in front; and it is much larger than is necessary for the size of the eye alone,—this delicate organ being cushioned on a quantity of soft fat, in order that it may move with the greatest ease in every direction. The inner walls of the orbits are parallel, while their outer walls diverge widely from one another, to give the eyes the advantage of as wide a range as possible, to accomplish which purpose we have seen that several provisions have already been made.

The *Lower Extremities* consist each of thirty bones. The *thigh* contains a single bone, the largest in the whole body. It has a long shaft, from which a neck goes off at an obtuse angle, surmounted by a smooth globular head, covered with cartilage, which is received into the socket that has been described as existing on the pelvis. Where the neck of the bone joins the shaft, there are two prominences which serve as levers for the attachment of strong muscles. The lower ends of the thigh-bones are large, and rest on the heads of the shin-bones. Their lower ends are much nearer one another than their upper ends, thus bringing the points of support underneath the weight of the body. The bones of the leg are two. The *shin-bone* is the inner and the larger, placed perpendicularly under the body,—it has a broad end above to articulate with the thigh-bone, and a smaller one below, to unite with the foot in the ankle-joint. One of its ridges is felt under the skin the whole way down, and is the part usually known as the shin. The outer slender bone, called the *fibula*, passes from the upper end of the shin-bone to the lower:

it is connected with the ankle-joint, but forms no part of the knee-joint; it has no connection with the thigh-bone, and therefore supports no part of the weight of the body. It serves to increase the breadth of the leg, without adding much to the weight, and is connected in its whole length to the shin-bone, by a strong membrane, or *interosseous ligament,* which serves to give attachment to muscles as well as if it had been bone, with the advantage of being much lighter. The lower ends of these two bones make the projections which are called the inner and outer ankles.

Intermediate to the thigh and leg is the *knee-pan,* a bone which corresponds to the elbow in the upper extremity. It glides on the smooth anterior part of the thigh-bone, is attached to the shin-bone by a strong ligament, and has the powerful extensor muscles of the leg inserted into it. It increases the power of these muscles, by throwing their attachment forward, and therefore farther from the centre of motion of the leg, thus conferring on them the advantage of a lever power.

The *Foot* consists of twenty-six bones. Seven of these form the *tarsus,* or solid part of the foot, to which no English word corresponds. Five compose the instep, or *metatarsus,* and the remaining fourteen are the joints of the toes. One of the bones of the *tarsus* is shaped above like a *pulley,* and is received between the projections of the two bones of the leg forming the two ankles, so that by its motion the foot is bent up at right angles to the leg, or pointed with the toes downward. The *bone of the heel* projects nearly an inch and-a-half backward, giving a strong lever for the insertion of the powerful muscles which form the calf of the leg. The next bone is in front of the pulley-like bone, and in some persons is very moveable, admitting of much lateral motion across the middle of the foot. Three *wedge-shaped,* and one *cuboid* bone, in front of these, complete the *tarsus,* and support the instep. The five bones of the *metatarsus* are each about two inches and-a-half long; they are attached posteriorly to the solid part of the foot, and anteriorly they support the toes. Their anterior ends rest upon the ground in standing, so that the foot presents an arch—the end of the heel-bone behind, and the ends of the metatarsal bones in front, being the abutments, while the pulley-like bone is the keystone on which the weight of the body rests. (See figure of skeleton.) This arch is not, however, firm or rigid, but yields a little when leant on; and to prevent its yielding too much, is strengthened below with strong ligaments, passing like a bow-string from behind forward. The degree of hollowness is very different in different persons, and those in whom it is most developed are always the most active, and the best pedestrians. The foot is arched also from side to side; and in the hollow thus gained, the blood-vessels, nerves, and tendons, going to the toes, lie secure from injury by pressure. The metatarsal bone of the great toe is much stronger than that of any of the others. To this toe there are only two moveable pieces, much larger than the joints of the other two. Each of the smaller toes has three pieces, similar to the joints of the fingers, but much smaller, as they are not intended for laying hold with. The last piece is enlarged towards its point, for supporting the nail on its upper, and the pulpy extremity of the toe on its lower surface.




The above figure represents the upper surface of right foot. P, pulley-shaped bone. H, heel-bone. N, navicular or boat-shaped bone. 1, 2, 3, first, second, and third, wedge-shaped bones. C, cuboid bone. 5, the five metatarsal bones. J, moveable joints of toes.

# MECHANICS.

## PART I.—STATICS.

## CHAPTER II.

### THE LAWS OF EQUILIBRIUM OF FORCES.

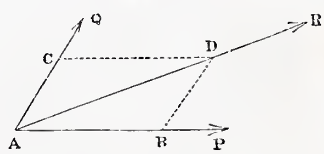
11. Variety of cases of equilibrium.—12. Parallelogram of forces.—13, 14. Equilibrium of three forces.—15. Superposition of forces in equilibrium.—16. Triangle of forces.—17, 18, 19. Equilibrium of many forces acting at one point: polygon of forces.—20. Resolution of oblique forces into perpendicular and horizontal forces.—21, 22, 23. Equilibrium of many forces in the same plane acting at different points—Moment of Force—Equality of moments.—24. Geometrical expression of this law.—25. Parallel forces.

11. The idea of equilibrium necessarily implies the idea of a plurality of forces, for one force by the definition produces motion. The simplest case of equilibrium of pressures is evidently that of two forces of equal magnitude, and acting in opposite directions on one point; in which the three elements of direction, magnitude, and point of application of forces are in their simplest relation. But as these elements may be variously combined in various systems of forces in equilibrium, there may be an infinite variety of particular cases. The conditions of equilibrium, however, are in all cases discoverable by the application of the fundamental law of the parallelogram of forces, now to be explained.

12. We may classify all systems of equilibrating forces into those in which the forces have a common point of application, and those in which they are applied to more than one point. And we shall consider first those systems of which the forces have their direction in one plane, noticing afterwards those of which the forces are not in one plane.

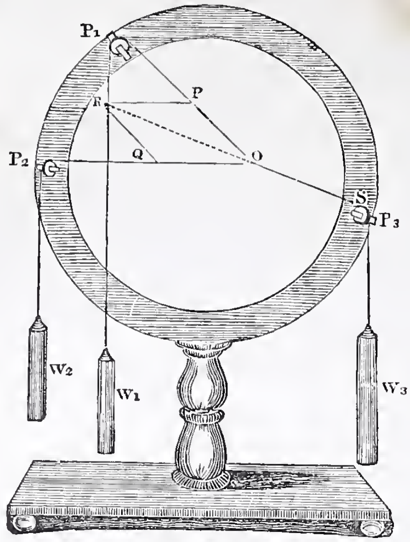
When two forces act together upon a point which are not in equilibrium, their statical effect must equal that of some third force acting singly at that point. The two former being compounded, are termed the *components,* in relation to the latter, which also is said to be the *resultant,* and which again may be *resolved* into the two.

The direction of two forces applied to a point, must either be in one straight line, or contain an angle at that point. In the first case, their resultant will be the sum of the forces, if acting in the same direction, and their difference if acting oppositely. We shall consider these cases more at large when we come to treat of the laws of motion. For illustration of the second case, let two forces act on the point A in the directions A P, A Q, and with magnitudes expressed by A B, A C; their resultant, or the single effect of their joint action, is invariably found to be represented also both in direction and magnitude by the diagonal of a parallelogram of which A B, A C, are the sides. Draw C D, B D, parallel to A B, A C, respectively, and draw the diagonal A D; then A D, acting on the point A, is their resultant. This remarkable law, termed the law of the parallelogram of forces, may be shortly stated, thus:—*If two forces be expressed by the adjacent sides of a parallelogram, their resultant is expressed in direction and magnitude by the diagonal.* This law is the foundation of all statical inquiries; in fact the principle runs through every ramification of the science.




13. Now since the diagonal represents in magnitude and direction the effect of the joint action of the two side forces, it is clear that by applying a force to the point of application, equal and opposite to the resultant or diagonal effect, the three forces thus acting on it would be in equilibrium.

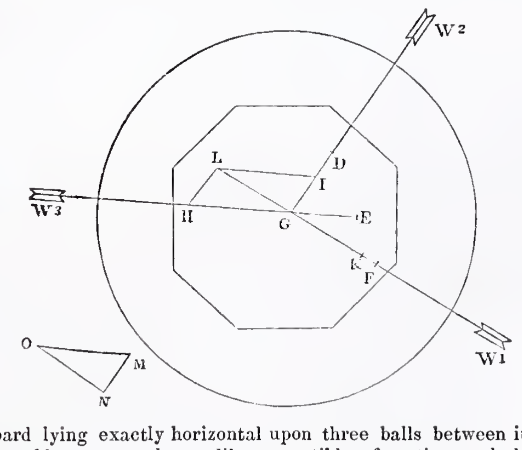
To prove this principle experimentally, take three weights, $W^1$, $W^2$, $W^3$, connected by cords of convenient length; and passing these over pulleys, $P^1$, $P^2$, $P^3$, fixed in a frame, let them hang till they settle in equilibrium. Then O, is the point at which the forces meet, being represented in direction by the cords; take O P, O Q, O S, along the cords, proportional to the weights $W^1$, $W^2$, $W^3$, respectively, and tracing the parallelogram O P R Q, on a surface behind, we shall find that the diagonal O R is




exactly equal and opposite to the line O S, showing that the components $w^1$, $w^2$, acting along their cords, on the point G, being expressed by the sides of a parallelogram, its diagonal will express their resultant, since it is equal and opposite to the force G S, exerted by the weight $w^3$, on the point G, and which keeps the other two in equilibrium. We may construct the parallelogram on either of the other two pairs, $w^1$ and $w^3$, or $w^2$ and $w^3$, and we shall find that the remaining third force in each case will balance the resultant found.

Hence, in general, any one of three forces in equilibrium, and acting on a point, will be expressed by a line equal and opposite to the diagonal of the parallelogram formed by the other two.

14. Another mode of making the experiment on three equilibrating forces, is to suspend over pulleys set at the edge of a round table, the three weights, $w^1$, $w^2$, $w^3$, by their cords, to different points in the surface of a plane board, as F, D, E; this




board lying exactly horizontal upon three balls between it and the table, so as to be readily susceptible of motion, and also to counteract its gravity, which, if not neutralized, would interfere as a fourth force with the equilibrium of the three. When the whole has come to rest, we shall observe that the direction of the cords, produced if necessary, have one common point of intersection, G, which corresponds to the same point, in the previous experiment. If now we measure as many inches G K, G I, G H, along the cords as there are pounds in the weights they sustain respectively, and complete the parallelogram G I L H, the diagonal G L is equal and opposite to G K, the third force in the system; that is, it is in the same straight line with G K, and contains as many inches as are in it.

Now these experiments give results quite general, as regards the equilibrium of the forces acting in one plane; for, though we have experimented with *gravitating* force only, yet, as before noted (3), the abstract pressure is essentially of the same nature, whatever be its source.

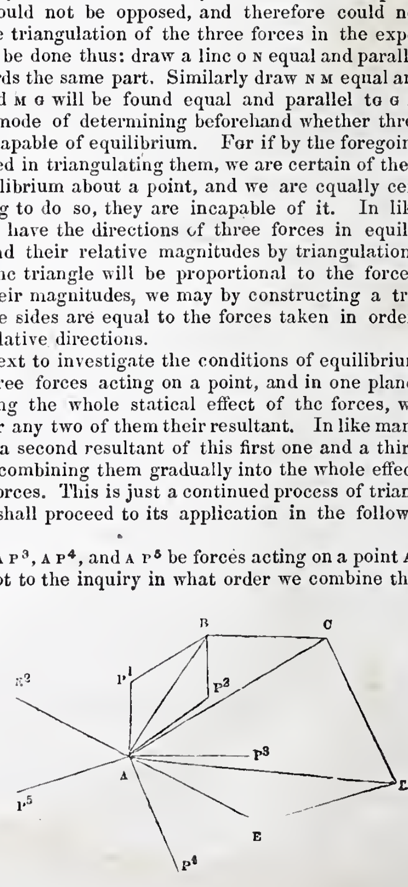
15. We have in this experiment touched on the doctrine of the *superposition of forces*. It is this: If a body be kept in equilibrium by any system of forces, and if to this be superadded another system of forces which would of themselves have kept it in equilibrium, then the resulting condition of the forces will still be equilibrium. For each system acts independently of the other, since what is called equilibrium of forces is the whole expenditure of their action among and against themselves—so that the two systems cannot interfere with each other, which is proved by experiment. In like manner, if from among a system of forces in equilibrium be abstracted a subordinate system of equilibrating forces, the remaining forces of the system must be in equilibrium. In the above experiment, we have the weight of the board itself, and the equal sum of the reactions of the balls as one system of equilibrating forces, and $w^1$, $w^2$, $w^3$, are the other equilibrating system.

16. Hitherto we have represented forces by the lines in which they act, expressing the three circumstances of direction, magnitude, and point of application. But it will often be preferable for purposes of reasoning to consider them represented by lines parallel to their direction and proportional to their magnitudes. Referring to the figure Art. 12, since C D is equal and parallel to A B, and D A is equal to and in the same line with the equilibrating force, the triangle A C D will represent by its sides A C, C D, D A, *taken in order*, the directions and magnitudes of the three forces. This may properly be called the *triangle of forces*. On the other hand, if the three sides of any triangle be taken to represent in magnitude and parallel direction, three forces acting on a point, they will be in equilibrium. For let three forces be represented in magnitude and direction by A C, C D, D A, acting on the point A, then the force represented by C D, is also represented by A B. Now A B and A C are equivalent to A D, that is, their effect is equal and opposite to that of D A, the remaining side of the triangle A C D, which will induce equilibrium. Therefore, if three forces acting on a point be represented in magnitude and direction by the three sides of a triangle taken in order, they will be in equilibrium.

The effects of forces are the same (10) at whatever points in their directions they be applied, so that the mutual intersection in one point of the directions of three forces is always necessary to their equilibrium, as was proved also by experiments (13) and (14), and it is easy to see that were they irreducible to one point of action, they would not be opposed, and therefore could not equilibrate. The triangulation of the three forces in the experiment (14), may be done thus: draw a line O N equal and parallel to G K, and towards the same part. Similarly draw N M equal and parallel to G I and M G will be found equal and parallel to G H. This suggests a mode of determining beforehand whether three given forces are capable of equilibrium. For if by the foregoing process we succeed in triangulating them, we are certain of their capability of equilibrium about a point, and we are equally certain that in failing to do so, they are incapable of it. In like manner, when we have the directions of three forces in equilibrium, we may find their relative magnitudes by triangulation; for the sides of the triangle will be proportional to the forces. Lastly, having their magnitudes, we may by constructing a triangle of which the sides are equal to the forces taken in order, ascertain their relative directions.

17. We have next to investigate the conditions of equilibrium of more than three forces acting on a point, and in one plane. Now, in estimating the whole statical effect of the forces, we may substitute for any two of them their resultant. In like manner, we may find a second resultant of this first one and a third force, and so on, combining them gradually into the whole effect of the system of forces. This is just a continued process of triangulation, and we shall proceed to its application in the following example:—

Let A $P^1$, A $P^2$, A $P^3$, A $P^4$, and A $P^5$ be forces acting on a point A. Now it matters not to the inquiry in what order we combine the forces; but we shall, for simplicity's sake, take them in their order of succession round the point A. The two forces A $P^1$, A $P^2$, being completed into a parallelogram by drawing $P^2$ B, $P^1$ B parallel to them, the dia-



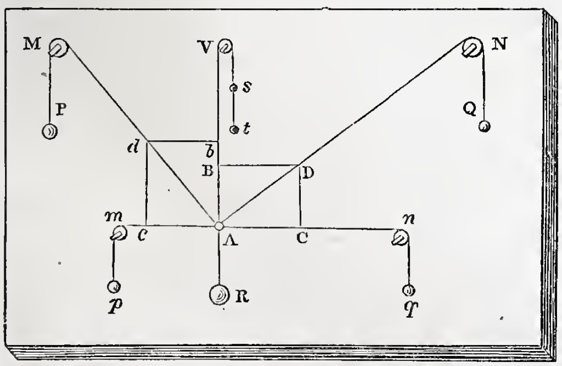
gonal A B is their resultant. Or we might at once have drawn P$^1$ B equal and parallel to A P$^3$, and toward the same part of the plane, and so get the resultant A B. To combine A B and A P$^3$ therefore, draw B C equal and parallel to A P$^3$, and A e is their resultant, and of course is the resultant also of A P$^1$, A P$^2$, A P$^3$. Again, draw e D equal and parallel to A P$^4$, the next force, and join A D for the next general resultant. Lastly, draw D E equal and parallel to the remaining force A P$^5$, and A E, the last resultant will represent the equivalent of the effects of the five forces. The point A, therefore, acted on by these forces is urged in the direction A E, by a force equal to it in magnitude. So that to establish equilibrium, we must add a new force A E$^2$, or system of forces, whose resultant is A E$^2$, equal and opposite to A E.

The figure A P$^1$ B e D E, being formed by drawing its sides successively equal and parallel to the forces A P$^1$, A P$^2$, &c., in constructing a like figure for any other system of forces, it is unnecessary to draw the several resultants A B, A C, &c. Such a figure, being many-sided is termed the polygon of the forces of the system from which it is constructed.

18. We might have found that A P$^5$ was equal and opposite to A D, the resultant of the other forces in the system, in which case there would have been an equilibrium. But as, in our example, we found the additional force A E$^2$ necessary to establish the equilibrium of the system, the polygon A P$^1$ B e D E will justly represent the system of equilibrating forces A P$^1$, A P$^2$, A P$^3$, A P$^4$, A P$^5$, and A E$^2$. The polygon must begin and end in the point A, that is, it must be complete, since the last resultant found by triangulation, which forms the last side of the polygon must be equal and opposite to the last force taken up, meeting it at A; and besides, were it not complete, we could join the two extremities by a line, which would represent the unbalanced effect of the system. Conversely, every system of forces, represented in magnitude and relative direction by the sides of a polygon, will be in equilibrium when applied to a point.

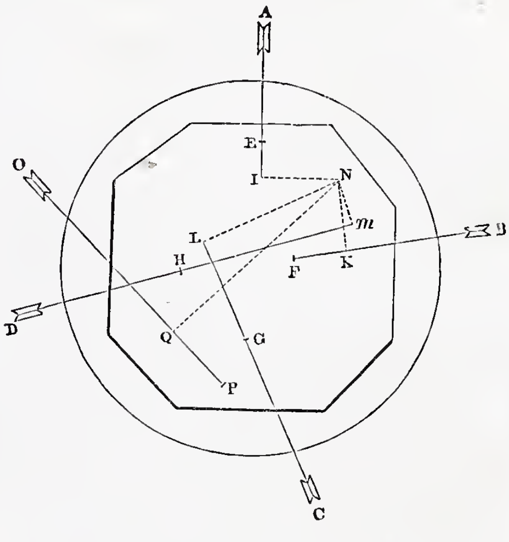
19. We may notice that both the magnitudes and the directions must be expressed, before we can certainly infer the equilibrium of more than three forces, by the method of the polygon. For, were the magnitude alone given, which let the sides of the polygon in Art. 17 represent, we might, by supposing the sides jointed at their extremities, compress or elongate the figure into various forms, and preserving the same length of sides, while the directions would clearly be altered. On the other hand, the directions of the forces might be correctly represented by the sides, and yet they might not express the relative magnitude of the forces; for, in the figure, Art. 17, E D may be moved into a position *e d* parallel to itself, and yet it alters the proportion of the sides e D, D E, E A; for while E D becomes longer, e D and A E are both shorter.

20. Another mode of investigating the action on a point of three or more forces in equilibrium, is to resolve them into two series of perpendicular and horizontal forces. Let there be two weights, P of five pounds and Q of four pounds, connected by a




cord, and hung over the pulleys, M, N, and somewhere on the cord, as at A, attach another weight, R, of six pounds and a half, so as the three may assume, in equilibrium, such a position as in the figure. Then the force R, will act vertically on the point A; produce the direction R A, upwards, and draw the horizontal line *m* A *n*. Then the oblique forces, P, Q, may be resolved into vertical and horizontal forces. Along A M, A N, take A *d*, equal to five inches, and A D equal to four inches long, having as many inches in their lengths, as there are pounds in the weights attached, P, Q. Draw *d b*, D B, parallel to *m n* and meeting A V, and draw *d c*, D e, parallel to A V, meeting *m n*. Then A *b* and A B will represent the effects of P and Q, in the vertical line R V, and A *c*, A e, their horizontal effects. In this way, the forces P Q, and R, are divided into two sets of forces, vertical and horizontal, acting at the point A. And as P, Q, R, are in equilibrium, the vertical forces will equilibrate too among themselves, and so also the horizontal forces. That is, R is equal to the two forces represented by A *b*, and A B; and A e, the resultant in one horizontal direction, is equal to A *c*, the opposite resultant. This may be proved by taking away the weights P and Q, and suspending others represented by their resultants. Thus, over a pulley at V, pass the cord A V, and attach to this the weight *s*, being as many pounds in weight as there are inches in A B; and another weight, *t*, containing as many pounds as there are inches in A *b*; then *s t* together, will balance the weight R exactly; that is, the vertical forces are in equilibrium. In the same way, over pulleys at *m*, *n*, pass cords attached to A, and suspend by them the weights *p*, *q*, containing as many pounds as there are inches in A *c*, A e, respectively. Then, these weights or forces, which are the horizontal ones, will also be in equilibrium. By the same kind of process, any number of oblique forces, acting on one point, may be resolved into vertical and horizontal equivalents, forming two subordinate systems of forces in equilibrium. It may be remarked too, that the above experiment thus affords an additional illustration of the doctrine of the superposition of forces in equilibrium.

21. We have now to consider the conditions of equilibrium of more than three forces in one plane, acting on different points. Let A, B, C, D, O, be any number of forces acting in a plane along the cords A E, B F, C G, D H, O P, on any points, E, F, G, H, P. When they have attained equilibrium, we may consider, for the sake of

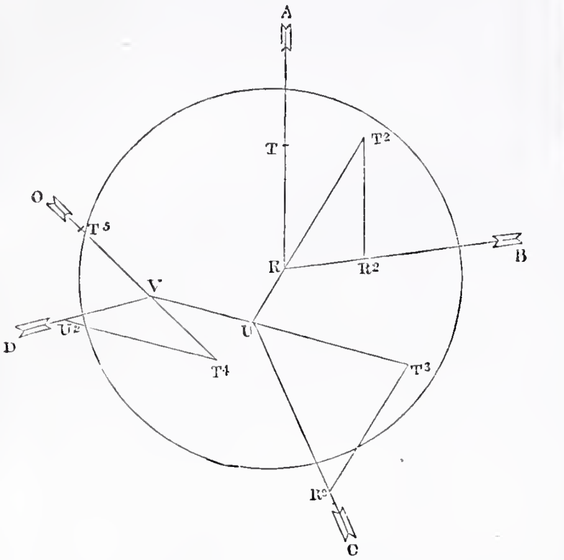



argument, any point N, in the surface experimented upon, to be fixed, without disturbing the equilibrium, since the surface is at rest at any rate, and as fixing merely prevents its motion. We may also view this point as a centre of motion round which the forces A, B, e, D, O, tend to turn the surface of the board acted on. Now, we know from experiment, that the effect of a given force applied to a point to turn it round another fixed point, is in proportion to the shortest distance of the fixed point from the direction of that force; namely, the perpendicular drawn from that point to the line of direction. And as the effect of the force must likewise be in proportion to its magnitude, its effect must be, upon the whole, proportional to these elements jointly, or in other words, to the product of its magnitude and distance from the centre. This is called the *moment* of force.

Draw, therefore, from the point N, the perpendiculars N I, N K N L, N M, N Q, to the directions A E, B F, &c., of the forces, produced if necessary; we shall find the moments of the forces by multiplying their magnitudes by their distances, as now drawn,

from N. And as their effects are proportional to their moments, it follows that the sum of the moments tending in one direction round N, is equal to the sum of the opposite moments. Thus, the forces A, O, and D, are opposed to the forces B, C, in reference to the point N. And, if we multiply A by N I, O by N Q, and D by N M; also B by N K, and C by N L, the sum of the first three products is equal to the sum of the last two. This principle is called that of the equality of moments, and is essential to the equilibrium of a system.

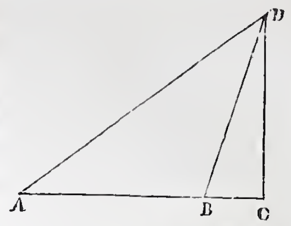
22. But there is another condition of the equilibrium of the forces, which is that, if they be transferred to any point, retaining their relative directions, they will be in equilibrium at that point. Let us combine them successively into one. Any two of the forces, A and B, being produced to meet in point R, their




joint effect is the same as if they had been directly applied to that point, and it will therefore be their resultant; which, by triangulation, will be R $T^2$, taking R T and R $R^2$, respectively, equal to A, and B, and drawing $R^2$ $T^2$ equal and parallel to R T. Again, producing $T^2$ R till it meet the next force C in U, take U $R^3$ equal to C, then the joint effect of R $T^2$ and U $R^3$, will be as before, their resultant acting at the point U; that is, drawing $R^3$ $T^3$ equal and parallel to R $T^2$, U $T^3$ will be their resultant. Lastly, producing $T^3$ U, till it meet the direction of the next force D in V, their effect together will be their resultant at V; taking V $U^2$ = D, and $U^2$ $T^4$, equal and parallel to U $T^3$, V $T^4$ is their resultant. It is evident then, that the sum of the effects of the forces A, B, C, D, acting at different points in the plane, must be equal to the force V $T^4$, acting at point V. Consequently, that the system of forces may be in equilibrium, V $T^4$ must be equal and opposite to the last force of the system represented by V $T^5$. Since, then, V $T^4$ is the resultant of the forces A, B, C, D; and O or V $T^5$ is their equilibrating force; these five forces must equilibrate if transferred to any point N, and will give a complete polygon of forces.—(18.)

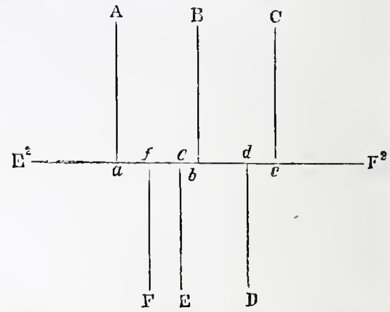
23. On the whole, then, though the principle of the polygon of forces be sufficient to prove the equilibrium of a system acting at one point, the additional principle of the equality of moments is necessary to establish the equilibrium of a system applied to different points. For any of the forces in the figure might be applied to another point in a parallel direction, and the polygon could yet be formed, but it would evidently affect the equilibrium of the forces. The equality of moments might likewise obtain without their being in equilibrium. For we might add an additional force to the system, passing through the point to which the moments are referred, without breaking the equality of moments. The two laws, therefore, of the polygon of pressures, and the equality of moments, are necessary, and, at the same time, sufficient as conditions of equilibrium.

24. We shall just notice an important geometrical form of the law of equality of moments. Let A B represent a force in magnitude and direction, then its moment in relation to any point, D, is equal to A B $\times$ D O, the perpendicular dropt on it from D. Now, join D A, D B. Then by a well known geometrical proposition, the area of the triangle D A B = A B $\times \frac{1}{2}$ D C. Consequently the moment of the force A B, in relation to D, is twice the area of that triangle. From this we have the following law:—"If we represent any number of forces acting in the same plane, and being in equilibrium,



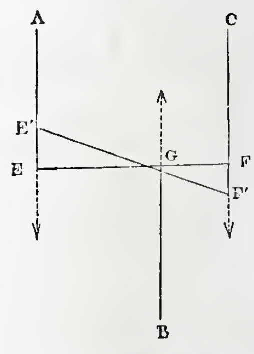

by lines, and join the extremities of all these lines with any point in the plane, the sum of the areas of the triangles thus formed which have for their bases forces tending to turn the system in one direction round the point shall be equal to the sum of those having for their bases those tending to turn it in the opposite direction."

25. Systems of parallel forces are particular cases of those just investigated; and, on account of their importance, they demand more specific examination. In those systems in which all act in the same plane, a line which is perpendicular to one, will be so to all. Let, therefore, A, B, C, D, E, F, be a system of parallel forces in equilibrium; let $E^2$ $F^2$ be a perpendicular to them. Produce their directions to meet it in *a*, *b*, *c*, *d*, *e*, *f*. Since they may act at any




points in their directions without affecting their equilibrium, suppose them applied at these points. Then applying the conditions of equilibrium, (22) in reference to the point $E^2$; or the sum of the moments or products of the three forces A, B, C, acting in one direction, into the distances *a* E, *b* C, *c* D, is equal to that of the moments of the forces D, E, F, acting oppositely. This condition secures their being properly placed along the line. And, again, their equilibrium about any point resolves itself into a case of action and reaction, as they then act in the same straight line in opposite directions. The sum of A, B, and C, in fact, must equal that of D, E, F.

In the case of three parallel forces acting on a straight line, two of them must be opposed to the third which must act between them, and be equal and opposite to their resultant. Let A, B, C, be three such forces applied to the line E F O. Then applying the equality of moments in reference to point O, A and C act in opposite directions, while B has no moment at all, as it acts directly on G. The moments of A and C, must, therefore, be equal about the point O; that is, A $\times$ E O = C $\times$ F G. From this, by proportion, we infer that A : C :: F G : E O; that is, the extreme forces are inversely as their distances from the middle one. In general, of three parallel forces acting in equilibrium on an inflexible line, the first in order is to the third, as the distance of the third from the second is to that of the first from the second; and the sum of the first and third is equal to the second. When A = C, then E G = F G. The theory of parallel forces is of great use in propositions about the centre of gravity, and applies also to the common lever.




If the line E F, in last figure, change its position for any obliquity with the forces, as the position E′ F′, then as G E, and O F, are still the distances of the forces A and C from G; the forces A, B, C, will yet be in equilibrium.

We shall next inquire into the conditions of equilibrium of systems of forces which do *not* act in the same plane.

# MATHEMATICS.

## CHAPTER VII.

### DECIMAL FRACTIONS.

1. We have seen in the preceding chapter, the necessity of reducing fractions to a common denominator, before we proceeded to find their sum or difference. We can therefore easily conceive that if a method could be devised of expressing all fractions, either exactly or near enough for all practical calculation, by others having a known common denominator, or which may be very easily reduced to others having such denominator, the process of calculation might be greatly simplified. Such a method has actually been devised, and constitutes the system of *Decimal Fractions.* In this system the denominator is always 10, or a multiple of 10, as 100, 1000, 10,000, 100,000, and so on, which are called *decimal numbers*, from their connexion with the number ten (*decem*). As examples

$$\frac{3}{10} \qquad \frac{71}{100} \qquad \frac{53}{1000} \qquad \frac{871}{100}$$

are decimal fractions, and differ in no respect from common or *vulgar* fractions, except in the greater simplicity of their notation. Every operation which we perform upon them must therefore depend upon the principles established in the preceding articles.

2. Before proceeding to show in what manner all fractions may be reduced, either exactly or approximately, to decimals, we may premise the following propositions.

I. Any decimal which has more figures in the numerator than there are ciphers in its denominator is greater than 1.

For example, the decimal $\frac{1234}{1000}$ is greater than 1.

For $\frac{1234}{1000}$ means $1234 \div 1000$ which is $1 + \frac{234}{1000}$

And similarly $\frac{4321}{1000}$ is $4 + \frac{321}{1000}$ and $\frac{4321}{100}$ is $43 + \frac{21}{100}$

II. Any decimal which has *not* more figures in the numerator than there are ciphers in its denominator is less than 1.

For example, $\frac{999}{1000}$ is less than 1. For 1 is $\frac{1000}{1000}$, consequently

$$\frac{1000}{1000} - \frac{999}{1000} = \frac{1000-999}{1000} = \frac{1}{1000}. \text{ Therefore } \frac{999}{1000} = 1 - \frac{1}{1000}$$

So similarly $\frac{731}{1000}$ is $1 - \frac{269}{1000}$ and $\frac{9119}{100000}$ is $1 - \frac{90881}{100000}$

3. The following will now be understood. If in any decimal greater than 1, as many figures be marked off by a point from the right of the numerator, as there are ciphers in the denominator, the figures on the left of this point will by themselves make the whole number which the fraction contains; and those on the right will be the numerator of a decimal of the same denomination as the given decimal, but less than 1.

For example, $\frac{1234}{10}$ pointed gives 123·4 and $\frac{1234}{10}$ is $123 + \frac{4}{10}$

$\frac{1234}{100}$ . . . 12·34 and $\frac{1234}{100}$ is $12 + \frac{34}{100}$

$\frac{1234}{1000}$ . . . 1·234 and $\frac{1234}{1000}$ is $1 + \frac{234}{1000}$

4. The next inquiry is the local values of the figures cut off to the right by the point. In connexion with this, we shall endeavour to explain that, if the numerator of a decimal be pointed according to the preceding rule, the first figure on the right of the point will denote *tenths*, the second *hundredths*, the third *thousandths*, and so on, of 1.

For example, the decimal $\frac{12345}{10000}$ when pointed is 1·2345

Now $12345 = 10000 + 2000 + 300 + 40 + 5$

and dividing each of these parts by 10000 as required by the fraction, we get

$$\frac{12345}{10000} = \frac{10000}{10000} + \frac{2000}{10000} + \frac{300}{10000} + \frac{40}{10000} + \frac{5}{10000}$$

But $\frac{10000}{10000} = 1 \qquad \frac{2000}{10000} = \frac{2}{10} \qquad \frac{300}{10000} = \frac{3}{100} \qquad \frac{40}{10000} = \frac{4}{1000}$

Therefore, $\frac{12345}{10000} = 1 + \frac{2}{10} + \frac{3}{100} + \frac{4}{1000} + \frac{5}{10000}$

5. If the number of *figures* in the numerator be the same as the number of *ciphers* in the denominator, the rule will still be true: for

$\frac{3456}{10000}$ pointed is ·3456 and decomposed is $\frac{3}{10} + \frac{4}{100} + \frac{5}{1000} + \frac{6}{10000}$

But if instead of $\frac{3456}{10000}$ we have $\frac{3456}{100000}$ and put a point before the whole numerator, thus ·3456, the rule will not be true, for

$$\frac{3456}{100000} = \frac{3}{100} + \frac{4}{1000} + \frac{5}{10000} + \frac{6}{100000}$$

where 3 is not *tenths* but *hundredths*. In order therefore that the rule may be true for this case, we must contrive to make 3 the second figure after the point. Now a cipher on the left does not alter the value of any number; we may therefore, instead of $\frac{3456}{100000}$ write $\frac{03456}{100000}$, and this last pointed by the rule is ·03456. Here the rule holds good, for

$$\frac{03456}{100000} = \frac{0}{10} + \frac{3}{100} + \frac{4}{1000} + \frac{5}{10000} + \frac{6}{100000}$$

which is the same as the preceding, since $\frac{0}{10}$ can only be 0. Similarly, when there are two ciphers in the denominator more than there are figures in the numerator, the rule will be true if we place two ciphers between the figures and the point. The following instances will show this more fully.

| Decimal. | Pointed. | Decomposed. |
|---|---|---|
| $\frac{1234}{100000}$ | ·01234 | $\frac{0}{10} + \frac{1}{100} + \frac{2}{1000} + \frac{3}{10000} + \frac{4}{100000}$ |
| $\frac{123}{100000}$ | ·00123 | $\frac{0}{10} + \frac{0}{100} + \frac{1}{1000} + \frac{2}{10000} + \frac{3}{100000}$ |
| $\frac{12}{100000}$ | ·00012 | $\frac{0}{10} + \frac{0}{100} + \frac{0}{1000} + \frac{1}{10000} + \frac{2}{100000}$ |
| $\frac{1}{100000}$ | ·00001 | $\frac{0}{10} + \frac{0}{100} + \frac{0}{1000} + \frac{0}{10000} + \frac{1}{100000}$ |

6. But as any decimal number is known as soon as the number of ciphers in it is known, it is clearly unnecessary to *write* such denominators as 10, 100, 1000, and so on, provided we put some mark upon the numerator expressive of the number of ciphers in the denominator. This mark is for our own selection, but the method adopted is, to cut off by a point, as already shown, as many figures from the right of the numerator, as there are ciphers in the denominator when that is possible. When there are more ciphers in the denominator than there are figures in the numerator, as many ciphers are placed before the numerator as make the number of figures and ciphers together equal to the number of ciphers in the denominator, and the point is prefixed to the ciphers. This point so placed is called the *decimal point.* The following table exhibits the circumstances of this scheme.

$\frac{1}{10}$ is written ·1 $\quad \frac{1}{100}$ is written ·01 $\quad \frac{1}{1000}$ is written ·001

$\frac{2}{10}$ is written ·2 $\quad \frac{2}{100}$ is written ·02 $\quad \frac{2}{1000}$ is written ·002

$\frac{3}{10}$ is written ·3 $\quad \frac{3}{100}$ is written ·03 $\quad \frac{3}{1000}$ is written ·003 &c.

$\frac{1}{10} + \frac{1}{300} + \frac{3}{1000} + \frac{4}{10000}$ is written ·1 + ·02 + ·003 + ·0004 &c.

$1\frac{23}{1000}$ is written 1·023 and is $1 + \frac{2}{100} + \frac{3}{1000}$ which is $\frac{1000 + 20 + 3}{1000} = \frac{1023}{1000}$

$1\frac{23}{10000}$ is written 1·0023 and is $1 + \frac{2}{1000} + \frac{3}{10000}$ which is $\frac{10000 + 20 + 3}{10000} = \frac{10023}{10000}$

$1\frac{2003}{10000}$ is written 1·2003 and is $1 + \frac{2}{10} + \frac{3}{10000}$ which is $\frac{10000 + 2000 + 3}{10000} = \frac{12003}{10000}$

$\frac{123}{1000}$ is $\frac{1}{10} + \frac{2}{100} + \frac{3}{10000}$ which is ·123; which is therefore ·1 + ·02 + ·003

$\frac{123}{10000}$ is $\frac{1}{100} + \frac{2}{1000} + \frac{3}{10000}$ which is ·0123; which is therefore ·01 + ·002 + ·0003

$\frac{123}{100000}$ is $\frac{1}{1000} + \frac{2}{10000} + \frac{3}{100000}$ which is ·00123; which is therefore ·001 + ·0002 + ·00003

7. From this it appears that there is the closest connexion between our scheme of writing decimals, and the decimal notation for whole numbers. If we take, for instance, the number 1111, we see that for every step which we make to the right, wo find a unit which is only *one-tenth* of the preceding unit. Let it be agreed, that the same method of valuation shall be continued further, and place a point after the unit's place to mark its position. Then in 1111·1111, the first one after the point will stand for one-tenth of the preceding, or one-tenth of the unit; the second for one-tenth of a tenth, or one-hundredth of the unit, the third for one-tenth of a hundredth, or one-thousandth of the unit, and so on, or,

$$1111\cdot1111 = 1000 + 100 + 10 + 1 + \frac{1}{10} + \frac{1}{100} + \frac{1}{1000} + \frac{1}{10000}$$

8. In this view of the subject the fundamental theorem of decimal fractions is this:—*All the quantity, such as it would be if the right hand digit were in the unit's place, may be taken as the numerator, and the denominator of the right hand figure as the denominator.* Thus,

$$123 \text{ is } \frac{1}{10} + \frac{2}{100} + \frac{3}{1000} \text{ which is } \frac{100}{1000} + \frac{20}{1000} + \frac{3}{1000} \text{ which is } \frac{123}{1000}$$

$$1\cdot102 \text{ is } 1 + \frac{1}{10} + \frac{2}{1000} \text{ which is } \frac{1000}{1000} + \frac{100}{1000} + \frac{2}{1000} \text{ which is } \frac{1102}{1000}$$

$$\cdot0123 \text{ is } \frac{1}{100} + \frac{2}{1000} + \frac{3}{10000} \text{ which is } \frac{100}{10000} + \frac{20}{10000} + \frac{3}{10000} \text{ which is } \frac{123}{10000}$$

At this point it will be useful exercise to prove by means of the principles of fractions generally, and the notations explained, that,

$$\cdot6543 = \frac{6543}{10000} = \cdot6 + .05 + \cdot004 + \cdot0003 = \frac{65}{100} + \frac{43}{10000}$$

$$17\cdot8427 = \frac{178427}{10000} = 17\,\frac{8427}{10000} = \frac{178}{10} + \frac{427}{10000} = \frac{17842}{1000} + \frac{7}{10000}$$

$$\cdot30012 = \cdot3001 + \cdot00002 = \frac{3}{10} + \frac{12}{100000} = \frac{30012}{100000}$$

9. From the principles explained these corollaries immediately follow:—

I. Any decimal is *multiplied* by 10 when the decimal point is removed one place to the right; by 100 when removed two places, and so on. Thus,

$$1234\cdot5 = 123\cdot45 \times 10 = 12.345 \quad \times 100 = 1\cdot2345 \quad \times 1000$$
$$123\cdot45 = 12\cdot345 \times 10 = 1\cdot2345 \quad \times 100 = \cdot12345 \quad \times 1000$$
$$12\cdot345 = 1\cdot2345 \times 10 = \cdot12345 \quad \times 100 = \cdot012345 \quad \times 1000$$
$$1\cdot2345 = \cdot12345 \times 10 = \cdot012345 \times 100 = \cdot0012345 \times 1000$$

II. Any decimal is *divided* by 10 when the decimal point is removed one place to the left; by 100 when removed two places, and so on. Thus,

$$1\cdot2345 = \frac{12\cdot345}{10} = \frac{123\cdot45}{100} = \frac{1234\cdot5}{1000} = \frac{12345}{10000}$$
$$12\cdot345 = \frac{123\cdot45}{10} = \frac{1234\cdot5}{100} = \frac{12345}{1000} = \frac{123450}{10000}$$
$$123\cdot45 = \frac{1234\cdot5}{10} = \frac{12345}{100} = \frac{123450}{1000} = \frac{1234500}{10000}$$

III. A decimal is not altered in value by annexing ciphers to it. Thus,

$$1\cdot2 = 1\cdot20 = 1.200 \text{ because } 1\cdot2 \text{ is } 1\frac{2}{10} = 1\frac{20}{100} = 1\frac{200}{1000}$$

IV. Decimals may be reduced to a common denominator by annexing ciphers to all which have a less number of places than that in which there is the greatest number of places, so that all may have the same number of places. To exemplify this, we have

| Fractions proposed. | | | | Reduced to a common denominator. | | | |
|---|---|---|---|---|---|---|---|
| ·1 | ·23 | ·131 | ·01 | ·100 | ·230 | ·131 | ·010 |
| 3·13 | ·733 | 73·2 | ·1 | 3·130 | ·733 | 73·200 | ·100 |
| 36 | 7856 | 1·2 | | 36·0000 | .7856 | 1·2000 | |
| ·01045 | 7.87 | 1·0001 | | ·01045 | 7·87000 | 1·00010 | |

10. We are now in a condition to consider the important problem of the reduction of a common fraction to a decimal without altering its value. This is effected upon the principle already established, that the numerator and denominator of any fraction may be both multiplied by any quantity, and afterwards divided by any quantity, without changing the value of the fraction. For example,

$$\tfrac{3}{8} \text{ is } \frac{3000}{80000} \text{ and } \frac{3000 \div 8}{8000 \div 8} = \frac{375}{1000} \text{ or } \cdot375$$

And similarly, $\frac{1}{25}$ is $\frac{100}{2500}$ and $\frac{100 \div 25}{2500 \div 25} = \frac{4}{100}$ or ·04

11. From these, and similar instances, we may deduce the following rule for the reduction of a common fraction to a decimal:—

*Annex ciphers to the numerator, and divide by the denominator until there is no remainder. The quotient will be the numerator of the required fraction, and the denominator will be 1, followed by as many ciphers as were used in obtaining the quotient. This result may be expressed according to the decimal notation.*

The operation may be simplified by proceeding according to the common modes of division. Let it, for example, be required to convert $\frac{31}{32}$ into an equivalent decimal fraction.

Operation.

```
32)3100000(96875
   288
   ---
    220
    192
    ---
     280
     256
     ---
      240
      224
      ---
       160
       160
```

The numerator of the required fraction is therefore 96875, and as *five* ciphers were annexed, the denominator is 100000, and consequently the fraction is $\frac{96875}{100000}$ which is represented by ·96875.

As we cannot always be sure before hand how many ciphers it is necessary to annex, in order to render the numerator divisible by the denominator, it is generally more convenient to proceed as if the number of ciphers were without end, and when the remainder becomes nothing, to stop, and count the number of ciphers which it has been found necessary to use. As an instance, suppose it required to find a decimal equivalent to the fraction $\frac{783}{625}$.

Operation.

```
625)783(12528
    625
    ---
    1580'
    1250
    ----
     3300'
     3125
     ----
      1750'
      1250
      ----
       5000'
       5000
```

The numerator of the required decimal is then 12528, and as *four* ciphers have been used, namely, those accented, the denominator is 10000. The fraction is therefore

$\frac{12528}{10000}$ which is 1·2528

If the numerator have ciphers on the right, they may be struck off instead of annexing ciphers to the numerator, observing that every cipher so struck off from the given denominator is equivalent to one annexed to the numerator, and must be counted as such.

It will afford the student some exercise at this point to verify the following examples of reduction.

| Fractions given | $\frac{1}{2}$ | $\frac{1}{4}$ | $\frac{1}{8}$ | $\frac{1}{20}$ | $\frac{73}{25}$ | $\frac{1}{500}$ | $\frac{7}{200}$ |
|---|---|---|---|---|---|---|---|
| To find | ·5 | ·25 | ·125 | ·05 | 2·96 | ·002 | ·035 |

| Fractions given | $\frac{1}{16}$ | $\frac{1}{32}$ | $\frac{1}{64}$ | $\frac{1}{625}$ | $\frac{1}{128}$ |
|---|---|---|---|---|---|
| To find | ·0625 | ·03125 | ·015625 | ·0016 | ·0078125 |

| Fractions given | $\frac{1}{512}$ | $\frac{63}{64}$ | $\frac{57}{16}$ | $\frac{89}{32}$ |
|---|---|---|---|---|
| To find | ·001953125 | ·984375 | 5·4375 | 2·78125 |

$\frac{71}{256} = \cdot277344140625$ $\qquad \frac{101}{4096} = \cdot024658178710375$

12. It is proved in algebra, that if a number be not divisible by a prime number, no multiplication of that number into itself will make it so. For instance, 10 not being divisible by 7, neither 10 × 10, nor 10 × 10 × 10 × 10 × &c., is divisible by 7.

*Consequence.*—Since 5 and 2 are the only prime numbers by which 10 is divisible, no fraction in its lowest terms can be converted into a decimal that will terminate, if there be any other prime factors, in its denominator, besides 2 and 5. For, in that case, the numerator contains none of the prime factors of the denominator, and no power of 10 contains them all; and, therefore, the numerator is not divisible by the denominator, however often it may be multiplied by 10.

For example, try to reduce $\frac{6}{7}$ to an equivalent decimal fraction.

$$\begin{array}{l} 7\underline{)60000000000000000000000000 \text{ \&c.}} \\ \cdot857142857142857142857142 \text{ \&c.} \end{array}$$

Here the quotient is a continued repetition of the figures 8, 5, 7, 1, 4, 2, in the same order. The fraction $\frac{6}{7}$ cannot therefore be reduced to a decimal fraction. Nevertheless, if we take as a numerator any number of the figures of the quotient 857142, &c., and as a denominator 1, followed by as many ciphers as were used in obtaining that part of the quotient, we shall get a decimal which differs from $\frac{6}{7}$ by a quantity which continually grows *less* as we put more figures in the numerator. This may be shown as follows :—

| | | | |
|---|---|---|---|
| $\frac{60}{7}$ gives the quotient | 8, and the remainder | 4, and is | $8\frac{4}{7}$ |
| $\frac{600}{7}$ . . . . | 85, . . . . | 5, . . | $85\frac{5}{7}$ |
| $\frac{6000}{7}$ . . . . | 857, . . . . | 1, . . | $857\frac{1}{7}$ |
| $\frac{60000}{7}$ . . . . | 8571, . . . . | 3, . . | $8571\frac{3}{7}$ |

and so on. Now, if two numbers do not differ by so much as 1, their tenth parts do not differ by so much as $\frac{1}{10}$, their hundredth parts by so much as $\frac{1}{100}$, their thousandth parts by so much as $\frac{1}{1000}$, and so on. Let it also be remembered that $\frac{6}{7}$ is the tenth part of $\frac{60}{7}$, the hundredth part of $\frac{600}{7}$, the thousandth part of $\frac{6000}{7}$, and so on. Then the following tables will be understood :—

| | | |
|---|---|---|
| $\frac{60}{7}$ does not differ from | 8 by so much as | 1 |
| $\frac{600}{7}$ . . . . | 85 . | 1 |
| $\frac{6000}{7}$ . . . | 857 . . | 1 |
| $\frac{60000}{7}$ . . . . | 8571 . . | 1 |
| &c. | &c. | &c. |

| | | |
|---|---|---|
| Therefore, $\frac{6}{7}$ does not differ from | $\frac{8}{10}$ or ·8 by so much as | $\frac{1}{10}$ or ·1 |
| $\frac{6}{7}$ . . . . | $\frac{85}{100}$ or ·85 . | $\frac{1}{100}$ or ·01 |
| $\frac{6}{7}$ . . . . | $\frac{857}{1000}$ or ·857 . | $\frac{1}{1000}$ or ·001 |
| $\frac{6}{7}$ . . . . | $\frac{8571}{10000}$ or ·8571 . | $\frac{1}{10000}$ or ·0001 |
| &c. | &c. | &c. |

So that, although we cannot find a decimal fraction exactly equal to $\frac{6}{7}$, we can find one which differs from it as little as we please.

It may be useful exercise for the student to make similar tables with the fractions $\frac{73}{81}$, $\frac{16}{17}$, $\frac{8}{31}$

The recurring quotient of $\frac{73}{81}$ is 901234567, 901234567 &c.

. . . $\frac{16}{17}$ is 9411764705882352,941 &c.

. . . . . $\frac{8}{31}$ is 258064516129032, 2580 &c.

13. These operations being understood, the following rule is plain :—

*To find a decimal fraction which shall be very nearly equal to a common fraction, proceed as in the last rule, and cut off from the quotient as many places as there were ciphers annexed to the numerator to obtain those places, for decimals. If one cipher was annexed, the decimal so obtained is within $\frac{1}{10}$ of the true value of the given fraction; if two ciphers were annexed, it is within $\frac{1}{100}$; if three ciphers, it is within $\frac{1}{1000}$, and so on.*

As an example, find a decimal which shall be within $\frac{1}{10000}$ of $\frac{9}{13}$. Annexing *four* ciphers to 9, and divide by 13, we get

$$90000 \div 13 = \text{quotient } 6923 \text{ and remainder } 1.$$

Cut off *four* places from 6923 and the answer ·6923 is within $\frac{1}{10000}$

For $\frac{9}{13} - \frac{6923}{10000} = \frac{90000-89999}{130000} = \frac{1}{130000}$ which is less than $\frac{1}{10000}$

It must be observed that when the quotient does not contain as many figures as there were ciphers annexed, as many ciphers are to be written on the left of it as will supply the number of places deficient, before prefixing the decimal point. The reason of this is obvious from the illustrations already given.

Take this example :—Find a decimal true within $\frac{1}{1000000}$ of $\frac{1}{1536}$

Annex *six* ciphers to 1. Then $\begin{cases} 1536)1000000(651 \\ \text{and remainder } 64. \end{cases}$

Make *six* decimal places in 651 which gives ·000651, the decimal fraction required.

*Verification.* $\frac{1}{1536} - \cdot000651$ is $\frac{1}{1536} - \frac{651}{1000000} = \frac{1}{24000000}$ which is less than $\frac{1}{1000000}$ as required.

For exercise—Find decimal fractions true within $\frac{1}{100000}$ of the following common fractions and verify the results.

| | | |
|---|---|---|
| $\frac{7}{9}$. *Ans.* ·77777 | $\frac{19}{7}$. *Ans.* 2·71428 | $\frac{37}{79}$ *Ans.* ·46835 |
| $\frac{5}{11}$. *Ans.* ·45454 | $\frac{4}{23}$. *Ans.* ·17391 | $\frac{1}{913}$ *Ans.* ·00109 |
| $\frac{3}{17}$. *Ans.* ·17647 | $\frac{1}{93}$. *Ans.* ·01075 | $\frac{243}{767}$ *Ans.* ·31681 |

*Definition.* A decimal fraction is said to be *true to the first, second, third,* or any other place, when any alteration in that place of figures would remove it farther from the truth than as it stands. For instance, the value of

$$\frac{5}{7} \text{ is between } \frac{714285}{1000000} \text{ or } \cdot714285 \text{ and } \frac{714286}{1000000} \text{ or } \cdot714286$$

$$\text{But } \frac{5}{7} - \frac{714285}{1000000} = \frac{5}{7000000} \text{ and } \frac{714286}{1000000} - \frac{5}{7} = \frac{2}{7000000}$$

·714286 is then not so much too great as ·714285 is too small and is therefore said to be true to six places of figures.

In illustration of these principles, we give this table :—

| The interminate quotient of | | shows that | | is more nearly | | |
|---|---|---|---|---|---|---|
| | $\frac{5}{9}$ being 55555 &c. | | $\frac{5}{9}$ | | ·5556 than | ·5555 |
| | $\frac{7}{11}$ . 63636 &c. | | $\frac{7}{11}$ | | ·6364 . | ·6363 |
| | $\frac{5}{13}$ . 3846 &c. | | $\frac{5}{13}$ | | ·385 . | ·384 |
| | $\frac{3}{277}$ . 1083 &c. | | $\frac{3}{277}$ | | ·0108 · | ·0109 |
| | $\frac{1}{129}$ . 7751 &c. | | $\frac{1}{129}$ | | ·00775 . | ·00776 |

From these operations, the following will be understood :—

*To make a decimal true to a given number of places, find one figure more than is wanted; if the last figure be 5 or upward increase the preceding by 1, and strike off the right hand digit.*

Thus : Suppose we find $\frac{11}{13} = \cdot846153,846$ &c.

| | | |
|---|---|---|
| If we wish to retain | one place only we write | ·8 |
| . . | two places . . | ·85 |
| . . | three places . . | ·846 |
| . . | four places . . | ·8462 |
| . . | five places . . | ·84615 |
| . . | six places . . | ·846154 |

If these principles be well understood, the student will find no difficulty in comprehending the arithmetic of decimal fractions, to which we shall next direct his attention.

# HISTORY.

## CHAPTER VII.

### ROME.—THIRD ERA.

In the first two sections we endeavoured to trace the growth and form of that mythological and legendary creed, which lorded it over the popular imagination of Rome, during the existence of the Roman republic, and the development of the municipal constitution. In reviewing the second era, we confined ourselves strictly to the internal or domestic affairs of Rome. This was not because the external or foreign relations of the state, during that period, were altogether uninteresting or unimportant; but because their importance is first fully felt in their consequences in the era at which we have now arrived, and during the lapse of which, the working of influences from without is the most prominent feature in the development of the Roman constitution. The principal events, in this third era of the history of the Roman republic, are those transactions by which the Romans subjected, one after another, all the states of Italy to their sway: it extends from the 387th year of the city—that in which the first plebeian consul was created, to the 490th, that in which the first Punic war commenced.

Only fourteen years before the election of the first plebeian consul, the city Rome had been sacked by the Gauls. Her allies had fallen off from her; her territory had been encroached upon by the neighbouring states; the walls of Servius Tullius, as they are called, enclosed almost all the territory the Romans could call their own. In so far as possessions beyond their city walls were concerned, they had, to use a common phrase, "to begin the world again." Their only resources were their own indomitable and indefatigable spirits, and the experience and skill they had acquired in their earlier struggles for ascendancy among their neighbours.

To understand and appreciate these early struggles, it is necessary that we bear strictly in mind the peculiarities of the country in which they took place. The transactions of the Romans, up to the commencement of the third era of the republic's history, may be regarded as entirely confined within that central semi-circular section of Italy, to which our attention has been already directed. The boundaries of this section are, the Tyrrhene, or lower sea; the Apennines, and that rising ground which stretches from the sources of the Anio towards cape Circeii. It extends a little northward of the Arno. From its northern extremity the Tiber flows, at the base of the Apennines, in a course parallel to the sea-coast, till it has swept across nearly two-thirds of the territory; and then turns suddenly to the sea. The Anio flows over one-third of the territory from the south, and mingles its waters with the Tiber, a little below the sudden bend we have mentioned. All between the eastern banks of the upper Tiber and upper Anio, and the summit of the Apennines, is a hilly rocky country, with fertile valleys interspersed. This country was inhabited by the Samnites, Sabines, and other confederated cities of Ascan extract. The country between the Arno, the Tiber, and the sea, was high and uneven, a land of extinct volcanoes, channelled and intersected by numerous streams; it was occupied by the confederated cities of the Etrurians. Southward of the Anio, and eastward from mount Algidus, was a tract of rising ground, which, after attaining a considerable height above the sea, subsided on the south, towards the plains of Campania, without having the summit-level marked by any very prominent range of hills. Southward of the Tiber, and around the base of mount Algidus, we have an extent of country rising by a gentle slope from the sea to the base of mount Algidus, and sweeping round that huge mound into the Campanian country. This was the country occupied by the confederated Latin cities, of which Rome was, in its infancy, one not of the highest note.

There was one feature of the internal organization of these states common to them all—whether they were of Etrurian or Ascan race, or, like the Latins, a mixture of Ascan and Greek. The whole range of country was dotted with abrupt hills fortified naturally with deep ravines, either altogether isolated, or connected to the surrounding table-land by a narrow isthmus easily susceptible of defence. The summits of these eminences never rise to such a height as to render the atmosphere inclement, and they are free from the marshy exhalations and miasma of the valleys. It was upon these that the clans of the country pitched their residence originally, both for the security and salubrity of the situation. In time they learned to fortify them; and the Cyclopean walls of huge blocks of stone, more or less artificially squared, and piled without mortar on one another—which as the first rude attempt at fortification originally diademed these steeps—may still be traced upon many of them; they have survived the shocks of war and devastation which have swept more elaborate and skilful monuments from the land. Each tribe dwelt within this huge circle of stones on its mountain aerie, and pastured its cattle in the marshes and forests which surrounded it. It was a practice of all these states (we have full written evidence of this), when their population became redundant, to decree a *ver sacrum*, or sacred spring. All the youth born in that year were consecrated to the tutelar deities of the state, as the founders of a new city; and when they reached an age sufficiently mature for the undertaking, were sent out to carry it into effect. These new-born cities retained a connexion of league and mutual amity with the parent state. The confederations, hence arising, were in course of time strengthened and augmented by voluntary accessions of other cities not thus connected, or by treaties,—the terminations of war. The bonds of these confederacies were drawn tighter by the frequent wars occurring among pastoral tribes who had plenty of time on their hands, who were all apt to entertain an overweening confidence in the strength of their hill-fastnesses, and who had plenty of opportunities of quarrelling afforded them, by the unsettled boundaries of the lands on which they pastured their flocks. But war, if it drew close the bands, also ruptured them at times. A captured city was forced to exchange its free membership of one league, for subjection to, and dependence on another. New confederacies thus arose, and old ones were extinguished. It is to this that we owe the alternate appearance and disappearance of the names of neighbouring states in Roman history—it is to this that we owe the impossibility which exists in many instances, of deciding how many cities belonged to a specific confederacy, or to what confederacy one individual city belonged. The great outlines of the Etrurian, Ascan, and the mixed or Latin tribes remain, but the limits of their domains, and the names of the confederacies occupying them, are continually shifting or changing.

It was amid these warlike, jealous, and narrow-minded states, that the foundations of Rome were laid. Like the Jews at the rebuilding of Jerusalem, the Roman citizens had to rear their walls with one hand, while the other grasped their weapons of war. Doubtless they possessed as much of the fighting devil which seems to possess all mankind as their neighbours; their subsequent history shows they did; but had they been as pacific by nature as the Society of Friends are by principle, they must, in the then state of Italy, have become warriors, or been exterminated. Before the foundations of Rome were laid, the cities of the Etrurians had been formed into one compact state, and in arts and arms, as well as other branches of civilization, had far outstripped all their neighbours. The Tiber alone intervened between them and Rome; they were ambitious of extended rule; and, notwithstanding the care taken by Roman authors, in the proud and powerful ages of their state, to obliterate the disgraceful record, there are still sufficient traces left in Roman history, to enable us to see that Rome was at one period hard pressed, if not, indeed, for a time, entirely subjected by the Etrurians. From the upper valleys of the Tiber and Anio, the rude Ascan tribes poured down upon her infant state. The Grecian invaders, from the north-east of Italy, were driving the aborigines across the summit of the Apennines, and as they came crowding over, one shoal after another, in huddling flight, those whom they found already settled there, were driven downward in the direction of Rome. Even from the kindred Latins came hostile assaults. Alba, in the infancy of Rome, had arrogated to itself a supremacy over the other cities of the Latin confederacy, and deference and submission were exacted from the new-born city of Rome, which its inhabitants were even then too proud to yield without a struggle. From all these causes, the men of Rome were exercised in war from the beginning. They were forced into battles, which taught them to feel the intoxicating excitement of the strife, and the rapture of conquest.

They contracted those tastes and habits which form the groundwork of the character of their state through all its future career.

Perhaps the accident of the peculiar formation of the territory on which the city stood had no small influence on the future destinies of its inhabitants. We have stated, that the inhabitants of the hill-forts throughout this portion of Italy were united into confederacies for mutual support. From the nature of their respective sites, there could be no closer organization among these communities. They were leagued for mutual defence against common enemies; sometimes the weaker would receive a chief magistrate from the stronger, or pay a tribute in token of acknowledged inferiority. But the internal government of each city was the exclusive business of the citizens, in which the other cities of the league did not interfere. Owing to the peculiar conformation of the *terrain* in which Rome stood, the walls, commonly called those of Servius Tullius, embraced within one common range of defence, no fewer than five settlements, originally independent. The inhabitants of these settlements were thus brought into a more intimate union, than the inhabitants of isolated and distant crags. There was greater room for the extension of the population than in the hill-forts; within the wide circling walls of Rome, the valley as well as the hill could be safely dwelt in. Down even to the third era of Rome's history, we can trace that jealousy and loathness to amalgamate, which animated the various tribes blended to form the Roman state, in the separate fortifications of the Aventine, Palatine, and Capitol. But we can also trace their mingling beyond the precincts of these their more especial homes. The forum in which they transacted their business was bounded by the river, and by the eminences we have named. The temple of Janus, the object of a common worship, stood where the territories of the Palatine and the Quirinal met. The river-like sewers of Rome, which served not only to carry down the filth of imperial Rome at her full growth, to the Tiber, but to drain the unhealthy marshy lower grounds of the stragglingly inhabited infant city, were built at a time of which no record has come down to us. Their peculiar structure marks them as the oldest monuments of man's hands about Rome. They must have been built, not so much to contribute to the cleanliness of a large and civilized city, but to render the lower grounds healthy, and fit for the residence of those who, rendered confident by the protecting enclosure of the city walls, wished to take up their abode in the enclosed valleys, when the fortified summits of the seven hills became too narrow to afford elbow-room for them all. The necessity created by this progressive amalgamation of at least three tribes, sprung from different races, of reconciling conflicts arising out of their differing and occasionally incompatible private laws, hastened the ripening of men's minds upon that important element of civil polity. A wider variety of social relations prevented the endurance of these narrow habits of thought necessarily retained in one unmixed people; the frequent necessity for adjusting jarring legal ordinances familiarized men's minds with a rude search after certain leading principles of jurisprudence. Above all, the circumstance of the later admission of independent settlements, after the government had been apportioned among the three original tribes, by calling into existence a high-spirited plebeian or unprivileged class, was of vital importance to Rome. In the old hill-forts of the other states of central Italy, there were but two classes—the citizens and the slaves; and there could be no others. The natural consequences ensued—the production of a servile, crouching, cunning, stubborn, mutinous spirit among the latter; of overweening tyrannical self-will among the former. To such states prosperity was death by mutual corruption; adversely, death by mutual hostility. In Rome, the unholy and corrupting element of slavery also existed from the first; but patrician arrogance was kept in check by plebeian freedom; and the habits of self-dependent labour, prevailing among a numerous class of the free citizens, checked for a time the dangerous increase of the slave population. From these circumstances, young Rome possessed in its own bosom the germs of a strength and civilization, more powerful, more rapid in its growth, more comprehensive and enduring, than that of any of the neighbouring states.

To this it was owing that the infant state was able to keep its ground and move, although hard pressed on all sides by states which had arrived at the maturity of their strength, and which compared with it, were powerful and wealthy states. Often was Rome reduced to extremities. While the Pelasgic settlement, *Roma*, properly so called, or the Palatine, was the state, we are led to believe by tradition, the Sabines at one time pitched their tents within the walls. Shortly after the expulsion of the Tarquins, the sovereign of Etruria was admittedly master of the Janiculum; and there is good reason to believe, that had not the vanity of the Roman writers led them to falsify their annals, we should read that the Romans were for a time subject to his yoke. This was about the 250th year of the city—in the 363d, it was sacked by the Gauls. The Capitol alone held out, and had not a mere accident—the gabbling of some geese, says the legend—awakened a citizen, when the stealthy feet of the Gaul already pressed the top of that rock, the name of Rome might have been nowhere found in history. But the ingredients in the constitution of Rome, upon which we have just been dwelling, lent a health and elasticity to it, enabling it to recover with what might almost seem preternatural rapidity from every reverse.

At a very early period, we find Rome acknowledged as head of the Latin confederate states. Polybius has preserved for us a treaty between Rome and Carthage, concluded in the year after the banishment of the Tarquins. This author tells us that he translated it from the brazen tables then existing in the Capitol, in the archives of the Ediles, the language being so obsolete, that in some parts, even the more learned among the Romans, could only guess at its meaning. We find in this document, the whole line of coast from the mouth of the Tiber to Circeii, called the Latin coast—the country itself Latium. Many of the cities in this range of territory are expressly enumerated as subject to Rome,—Ardea, Antium, Aricia, Circeii, and Terracina. Rome stipulates directly for these as well as for herself. The Carthaginians bind themselves to Rome, not to make conquests or build forts, even in the independent portions of this region. The Romans and their allies, on the other hand, are inhibited from sailing into any harbours south of the Beautiful or Hernican cape, which forms the eastern boundary of the gulf of Carthage. In the middle ground of Sicily equal privileges are secured to the Carthaginian and Roman merchants. At Carthage and on the Libyan coast, to the west of the Hernican cape, the Romans might land and traffic; but the sale of the cargoes was to be by public auction, and in that case, the state was pledged to the foreign merchant for his payment. The terms of this treaty do not so conclusively establish a considerable development of mercantile enterprise at this early period in Rome as at first sight appears. Aristotle mentions treaties concluded between the Carthaginians and the Etrurians, masters of the western Italian coast, north of the Tiber, about the same period, and in nearly the same terms. The object of the ambitious Carthaginians evidently was to secure for themselves a monopoly of the trade of the interior Mediterranean—to render their town an entrepôt between the states within and the states without the narrow part of that great inland basin between the extremity of Italy and the cape on which Carthage was situated. Having secured themselves by treaties against the actual rivalry of the Etrurian cities, they may have thought it as well to make assurance doubly sure, by shutting the door against the contingent possibility of rivalry from the Latins. There may have been commercial enterprise among the Latin states at that time—there may have been commercial enterprise even at Rome; but it does not necessarily follow that there was, from the terms of a treaty which may have been framed to preclude future as well as existing competition. But it is clear from the terms of the treaty, that it was concluded with Rome as the sovereign of several Latin cities, and as at that time the most influential and responsible member of the Latin confederation. Nor can we wonder that such was the case, young though Rome was in comparison with many of the others, when we remember the more powerful and varied elements of strength and activity in her original constitution. Of this ascendancy, Rome was deprived by inroads of the Etrurians, at that time far an overmatch for her. She was stript of everything without the city walls, if even their precincts remained unviolated by the march of the invader. But the Etrurian power and civilization had reached their height. Their cities were corrupted and weakened by the full development of the character of the despot or the slave, among all their inhabitants. They were merely an aggregate of mutually jealous communities; there was no incorporating union among them. The few originally independent settlements, of which Rome was composed, were thoroughly in-

corporated; and from their union had sprung the sturdy plebeian class, among which was nourished hatred of oppression, uncontaminated, in the great majority of instances, by the power to oppress. This jealous and watchful body forced patrician pride, although always liable to break out, to preserve, on the whole, some regard to appearances. This constitution proved itself, in the long run, more than a match for the less coherent Etrurian power. It was compact thews and sinews against diffused colossal bulk—it was youth against age. Rome first threw off the yoke then mastered one and then another Etrurian city, breaking up and paralyzing the league. Once able to take the field on equal terms with the Etrurians, Rome speedily regained her ascendancy among the kindred Latin tribes. Thus reinstated in power, she turned upon the Ascans who had taken advantage of her weakness, while succumbing to the Etruscan power, to press upon her from the upper Anio, and soon made them feel her strength so effectively, that a treaty was struck up, incorporating the Hernici—the Ascan confederation immediately adjoining Rome with the Latin. In this prosperous career the city continued advancing, until the whole semicircular central district of Italy felt and owned her influence. At this period of her career she came into contact with the Gauls. Some such influences as about the close of the Roman empire set the Germanic tribes in motion, had at that time driven the Transalpine Celts down upon the valley of the Po. The Romans having by this time contracted that inveterate itch for intermeddling in everybody's affairs, which marked their whole future career, must needs send envoys across the Apennines to negotiate between the overreaching Gauls, and some friendly Italian states. The envoys were young, unreflecting, and full of the Roman ardour for adventure. Forgetful of the important and sacred character with which he was clothed, one of them engaged in a sally against the Gauls, and was recognised by them. Excited by victory, lured by the hope of greater wealth to plunder in a sunnier clime, the Celts sought nothing better than a cause of quarrel with Rome. "Towards Rome! towards the faithless and perfidious city!" was the cry, and the locust-swarm moved onward,—no regular organized army, but a mass of living beings, the foremost of whom threw themselves upon the enemy's arms; and thus entangling them, left their bearers defenceless against the blows of those who followed. The art of war was vain against such a deluge. The warriors of central Italy were swept from the face of the earth, where the Celtic hordes passed, as the herbage where locust-cloud passes over. Down every defile and mountain-pass converging to Rome, their myriads swarmed. Army after army was swept away by their surge, and the walls of Rome crumbled beneath their assault. The Capitol was the Roman state. But once more the sanguine hope and stubborn pertinacity of the Romans proved themselves an overmatch for mere brute force. The invaders, wearied out by the protracted resistance of the Capitol, with the fickleness of savages relinquished the attempt to take it, and dispersed on all sides in search of fresh booty. Once fairly scattered, Roman discipline quickly cut them up in detail.

Before concluding this review of the foundation-laying of Roman foreign policy, it will be expedient to stop and regard it closely, in order to form a just and accurate conception of its characteristic features. The records of these early struggles for empire within a limited space are scanty; but as far as we can judge of them, the conquests of Rome were rather forced upon that city than sought by it systematically. The battle-field was a narrow one. The various struggles seemed for themselves of no greater importance, than the moss-trooping raids and forays of our own borderers, three or four centuries ago. Like these there is a picturesque and individual interest attaching to them, rendering them fit themes of poetry and romance. The topography of the environs of Rome, by Sir William Gall, derives from this circumstance an attractive power, akin to that possessed by the prose narrative in Scott's Border Minstrelsy. Along every ravine, where mountain-streams fret along their deep, narrow, and tortuous channels, beneath the shade of old trees, we find enduring monuments of these times,—the colossal stones of the old ramparts, girdling isolated rocks, where Veii, Crustumenæ, or Corioli stood. In this mountain-pass, the whole house of the Fabii perished: that isolated height is most probably the castle which they held on the frontiers of the Roman territory—Rome itself not being five miles distant. Upon this parched and barren plain, Coriolanus bowed the stubborn knee, and exclaimed, "Oh mother, mother, you have saved your country, but lost your son!" Here is the mountain-lake, on the banks of which the enthusiastic chivalry of Rome persuaded themselves that they saw Castor and Pollux mounted on white horses fighting at their head. Here, in this secluded glen, where the deep noiseless water laves abrupt precipices perforated by myriads of sepulchral monuments, repose the bones of the citizens of Cære, within whose walls, the most sacred objects of Rome found shelter and security, when the rude Gaul stared with brute awe at the hoary fathers of the state, seated sternly majestic in the forum, and growled before them, ere he ventured to dabble his butcher hands in their blood. At the bend of the Tiber, ere it receives the Anio's waters, on its northern bank is a country extending to the base of Soracte, famous in the earliest traditions of Rome, for its luxuriant fruit-trees, covered with them still as with a dense forest, although no man heeds or cares for them. In their central shade is the vestigeless site of a mute oracle. Man's jugglery, man's passions, play their apish fantastic tricks, and desolate a small space and evaporate; but the spirit of the beautiful and the useful breathes on untiring, undecaying, even when no man regards it. The natural landmarks of this land are as of old. Soracte and mount Algidus still gaze upon each other across the valley of the Tiber; the spectator, perched on either mountain, may see now, as in the days of old, the living sunshine poured down in floods o'er crag, and stream, and tree; or the storm-drift urged by the wind-eddies across its surface, in strange, shifting, vapoury forms; but the departed—a sympathy with whose emotions lend its chief interest to the scene,—why, the very dry dust of their last mouldering remnants must long ago have been blown by the rude winds away into the bosom of the deep! And yet we can feel with them, when we read their history, as if they were living still. Strange power of human passion, to stir, by contagious sympathy, those who are removed from its subjects by thousands of years.

There is scarcely a country which does not possess chivalrous legends as interesting as those of Rome. There is scarcely a country over the surface of which the hand of God has not scattered glades and dales with a surpassing and characteristic beauty of their own, to which these old legends lend an awe-inspiring spirit. In this, however, do those early warlike achievements of Rome differ from all others. With the majority of people, mere petty wastes of strength constitute their history; with Rome they were but the play of the boy-giant, unconsciously training himself for future labours. The capture of the paltry mountain-citadel of Veii, after a siege protracted for years, is in itself an incident of as little importance, as the storming of some moss-trooper's marauding hold; but it was by a repetition of such exploits, that the Romans learned their tactics and contracted their lust of conquest. By experience in war, animated by a growing mechanical skill, the contingents of their tribes became legions, dispersed in ranks, and marshalled in centuries. The necessity of keeping a hold upon an enemy once conquered, lest, left to recruit his vigour, he should return to the assault with increased physical strength, and with redoubled motives to vindictiveness, avarice of spoil, and eagerness to efface the shame of defeat, suggested a new mode of colonization. The peculiar conformation of the city of Rome superseded, in a great measure, the necessity of colonies, swarming off from the present time by means of the *ver sacrum*, or sacred spring. But with a view to keep in subjection conquered states, colonies were settled, not on fresh unbroken lands, but in the already settled states. The conquered city was amerced in a portion of its lands. Portions of these were disposed of by lot to such Roman citizens as were willing to settle as a colony among the new subjects. This body served the purpose of a garrison to keep the vanquished from revolt; and their fidelity was assured by the ill-will naturally entertained by the old citizens to intruders, not merely upon their fields, but into their very fire-sides. By this means, Rome maintained, at no expense, garrisons carefully thrown out on every side, in such a manner, as to be able to relieve each other, and thus secure themselves until succour was obtained from the city. Tribute was derived into the public exchequer from these dependent states; and contributions were exacted, under specious pretexts, from the independent cities of the Hernican and Latin confederacy, to which many cities of the old Etrurian league had acceded,—the Roman garrisons scattered among them under the name of colonies affording guarantees for the regular payment of the quotas. The commencement of

this system of Roman rule over the central Latin states belongs to the second era. The reverse occasioned by the invasion of the Gauls interrupted it only for a moment; and was ultimately the occasion of accelerating its progress. The strength of Rome was shaken by the rude grapple of the Celts; but that of the other cities, over which their swarm passed, was utterly prostrated. They fell an easy prey to the recurring energies of Rome; and Rome had by this time contracted an insatiable appetite for conquest. Pride and avarice alike spurred it on. Victory and defeat had alike contributed to increase its warlike skill. We had occasion to observe in last chapter, that one of the oldest deities of Rome was Jupiter Stator—the god who inspired the Romans with a disdain of turning their backs. Coeval with him is the worship of the god Terminus—the god of boundaries. The veneration entertained for this divinity forbade the Romans ever to desert the limits to which their territory had been extended. To advance the boundaries of the Roman state was a sacrifice worthy of the god; but what had thus been once consecrated to him, must be preserved inviolate from foreign masterdom at any cost. Thus, among the Romans, as among every people, was imagination called into play, to consecrate and strengthen the suggestions of less noble faculties of our nature. Thus were arrogance and avarice glossed over with the specious face of a national religion. From his boyhood, the young Roman had the doctrine of a fanaticism for conquest instilled into him; and this sordid superstition worked as powerfully and enduringly upon his mind, as the delights of Mahomet's paradise upon the imagination of the Arabs. With a dogged and stubborn resolution, the Romans set themselves to master all with whom they came in contact; and they persevered until they had brought to their feet, a world infinitely wider than the most learned among them could have conjectured to exist when they undertook the task.

At the commencement of the third of the eras into which we have divided our review of Roman history, the city of Rome was eventually sovereign of the central division. This, however, was a position in which they could not remain stationary. The Etruscan tribes extended beyond the Arno to the north; the Ascan tribes extended beyond the Apennines to the east; and southward they hemmed in the Latin territory, and stretched from sea to sea. While the great masses of these races retained their independence, those of them subjected to the sway of Rome had constant encouragement to seek redress of every grievance by revolt. They fancied they saw an inexhaustible reserve of military force in the unsubdued tribes of their race. The Romans found themselves within an enchanted circle, from every point in the circumference of which they were at the most unexpected moments liable to assault. They were willing enough to push forward their conquests; and the necessity of self-defence combined with this stimulus to urge them on. The Roman armies penetrated northward to the banks of the Po, never retiring without leaving garrisons under the specious name of colonies behind them. In the south they advanced over the necks of the gallant Samnites into Lucania and Apulia, where they found themselves brought into collision with new neighbours,—the Grecian cities which had colonized, after the Greek fashion, the south of Italy. In the prosecution of their schemes of conquest over these states, the Romans were called upon to measure their strength with a more formidable enemy than they had yet encountered. The city of Tarentum, the most powerful among the cities of Magna Græcia, occupying the southern extremity of Italy, beheld the advance of the Romans with sensations pretty similar to what the descendants of those same Romans viewed the approach of the Teutonic tribes at the downfall of the Western empire. The Tarentines called in the arms of Pyrrhus to their aid,—the ambitious monarch, who at that time swayed the sceptre of that portion of what had been Alexander's empire, designated Epire. The Romans were allured by the prospect of wealth and luxury, such as they had never known before, in the possession of a highly refined, but enervated people. And as they were rushing to the spoil, they found their career arrested for a moment by the interposition of the Macedonian phalanx, flanked and strengthened by all that was powerful and imposing in Asiatic warfare. This temporary check did little more, however, than teach the Romans wary concentration of force, and confidence in their own resources. Pyrrhus obeyed the call of the Tarentines, more for the purpose of serving himself than them. Having twice or thrice measured his strength with the Romans, and found that little was to be got in Italy beyond hard fighting, pride would not allow him to retire altogether from the war into which he had rushed; but he kept it up only for the sake of saving appearances. He committed the defence of Tarentum to one of his officers. Two years after his departure, the Romans made themselves masters of the city, and thus completed the conquest of Italy, south of the Po.

A greater change was produced in the frame-work of Roman government, and in the constitution of Roman society, by these conquests, than was at first apparent. The names of the different civil and military offices, and the mode of appointment, remained unchanged, and the many never look below the surface. Everything at Rome, however, was altered, though at first it appeared not. Pygmalion's statue, when it warmed into flesh and blood, did not undergo a more entire and essential change.

The Romans had for some time discontinued the practice of admitting captives into the number of their people. The most favourably treated of the vanquished were allowed to remain freemen, with exclusion from all the rights of a citizen. The Latins were the most favoured of Italian races, and stood next to the citizens. The inhabitants of municipalities, and the natives of the colonies came next. The Roman citizens employed to found colonies retained their right of citizenship. Thus was the whole of Italy erected into one state, of which the city of Rome was sovereign. The magistrates of Rome, elected by the citizens, were the executive government, and the judges in last resort of this state. The mass of its free inhabitants possessed no civil rights, any more than the subjects of the most despotic monarch. The executive government and judges were noways responsible to them. They were elected by, they paid their court to, they acted for, the selfish interests of a privileged few, the citizens of Rome. The unprivileged many were kept in obedience by the system of settling armed garrisons among them, under the name of colonies. The Roman colonists acted in the interests of the general body. Their loyalty to Rome was ensured by allotments of rich land—by allowing them to feel the consequence attaching to them as Roman citizens, amid a crowd who never could attain to this distinction—and by the consciousness that, having incurred by their arrogance and share in the spoil the ill-will of those among whom they lived, their only safety consisted in earning by their fidelity, support from central Rome. The magistrates nominally elected by the whole citizens were, *de facto*, elected by those only who remained close residenters of the city. These consisted mainly of two classes,—the very wealthy and powerful, who were kept at home, by ambition and love of intrigue; and the very poor, who had not interest enough with the dispensers of employment, even to obtain a desperate chance of mending their fortunes abroad. Such rude wealth, as the people in their then state of refinement could estimate, continued to flow in under the name of tributes, or of tokens of friendship from independent states, during the whole of the third era. It was rendered available by the parties in possession of office—that is, of the senators to influence the elections. In one sense, the distinction between patrician and plebeian was growing obsolete; for many plebeian houses had risen to an equality with the patrician. But these had lost all common interest with the mass of plebeians; and the distinction between them was involved by the circumstance of all the intelligence and energy of the less wealthy of the plebeian rank being tempted abroad, leaving only the indolent and less worthy at home. The permanent inhabitants of the city came soon to consist of a small knot of wealthy and ambitious intriguers, and an idle and venal rabble dependent for the supply of its wants upon largesses doled out from the public treasury. And it so happened, that in proportion as the permanent inhabitants of the city sank in worth, the consciousness that their city was the metropolis of Italy—that they were its sovereigns trampling daily on the necks of what had once been sovereign and independent states—inflated them with pride. Their corruption was further increased towards the close of the era, by the conquest of the Greek cities in the south of Italy. "In former times," says Florus, "the victorious generals of Rome exhibited in their triumphs herds of cattle, driven from the Sabines and Volsci, the empty cars of the Gauls, and the broken arms of the Samnites: but in that which was exhibited for the conquest of Tarentum, the procession was led by Thessalian and Macedonian captives, followed with carriages loaded with precious furniture, with pictures, statues, plate, and other ornaments of silver and gold." The acquisition of luxuries, however elegant, by a rude people, is always fatal. The Romans

were not at that time capable of appreciating the refined taste and imagination which spoke out in the works of art they had appropriated. But they could taste the debauchery in which their former proprietors indulged, and appreciate the power of wealth to procure such coarse pleasure. The Romans learned the vice of wealth and luxury, before they learned their refinement: they blended the coarse violence of the savage with the excessive indulgence of nations, refined even to effeminacy,—political corruption, private debauchery, overweening pride; and yet the vigour of the national character was not sapped. No, because even as young and robust individuals may indulge in excess for a time, without suffering in their health—which would kill weaker subjects, or more aged persons—so the young vigour of the Roman constitution bore it a while scatheless, through these enfeebling influences. So much of the old constitution was retained, that the Roman people, as a body, was still regarded as the great army of the state. In emergencies—and they were of sufficiently frequent recurrence to prevent military virtue from slumbering—all were liable to serve. The extent of the city's territories—the frequent revolts among her half-subdued subjects—the frequent wars, rendered necessary by encroachments on her extended frontier, forced her to keep permanent armies in the field,—and these were ever open schools of hardihood and skill in swaying the minds of men. These became in time not merely the means of enforcing the payment of that tribute upon which the metropolis subsisted, but the means also of keeping that metropolis in obedience to law. The rivalry, moreover, of the great patrician and plebeian houses was of itself sufficient to keep the rulers of the state from utter degeneracy. An aristocracy, (and such the Roman state now was, the citizens of Rome being the nobles,) is a more oppressive government than a pure despotism; but it is more prolific of great, if not exactly of good men. There was another cause which cooperated to keep fresh and vigorous the mind of Rome. Its empire was recent, secured by no completeness of the mechanical apparatus of government. Only so long as other states felt the superiority of Roman genius was the Roman ascendancy secure. It was not mere superior skill in arms that could effect this. Rome was now the court of appeal from all the states subject to her sway; these states must be taught that at Rome there was greater store of legal wisdom than among themselves. Nor was even intellectual ascendancy sufficient. One great secret of Roman success was the constant ostentation of the virtue of justice. It would not have been safe to drop the mask too soon; and often men, by affecting a virtue, end by believing they possess it, and acting nearly as well as if they did. Thus did the necessity of constant activity, and the necessity of preserving appearances, save the Romans from utter and premature corruption. Amiable they were not; good we can scarcely call them; but with all their faults, they were the wisest, most just, and most energetic rulers of a state the world had then witnessed. The length of time they were able to uphold an empire based from the beginning upon a rickety foundation, and still more the indestructibility of many of their laws and institutions, which have survived even their long-lived empire, are a sufficient guarantee of this. The elements of anarchy which slumbered undeveloped in their state at the period we have now reached, but which soon disclosed themselves and their tremendous and ultimately fatal workings, will form the topics of the fourth and fifth eras, and afford matter for one more chapter; after which, we shall shift the scene for a time, to a land more fertile in wonders.

## ON THE MANUFACTURE OF CAST-IRON.

### CHAPTER I.

IRREGULARITIES OF THE SMELTING FURNACE.

By John Hart, Esq.

The stimulus which has so recently been given to the iron manufacture by the introduction of railroads and steam navigation, when viewed in connection with our almost inexhaustible coal fields, and the beds of ironstone, with which this island is now discovered to abound, together with the numerous iron works which are at present erecting throughout the country, plainly indicate that the manufacturing of iron is, in all appearance, likely soon to rival, if not to surpass, that exotic the cotton manufacture; and, like the tin of Cornwall, the iron also is for ages destined to become another of the staple productions of our *Ultima Thule*. However, from the curious anomalies that are said so frequently to occur in the working of the smelting furnace, it is evident that in the present state of our knowledge with regard to this manufacture, we have still much to learn, the more especially since we perceive such diversity of opinions among the iron-smelters themselves, about the nature of the operations in which they are engaged. These differences of opinion among practical men at once point this out as a proper subject for investigation. I shall therefore, in the first place, notice a few of the prevailing opinions which are at present entertained by several of the iron-smelters, and then endeavour to investigate how far these opinions are consistent with the known laws of combustion and chemical affinities. Afterward I shall state what I conceive to be the true cause of these anomalies, and also the probable means of obviating them in future.

Practical men inform us that the profitable working of their furnaces depends very much upon the attention of the keeper, who must carefully watch every indication of change, and take his measures accordingly; still, notwithstanding his utmost care, he is unable always to keep the furnace in the most advantageous state of working, and what is more extraordinary still, he is unable to account for these changes that so frequently occur—sometimes the charge sinks quickly down; in that case the furnace is said to be driving fast; at other times it sinks more gradually, and then the furnace is said to be driving slow. "These changes," says an able writer on this subject, "are connected with, or caused by, other accompanying facts, though we are ignorant how this connexion exists; often indeed our knowledge does not extend so far."

I shall now endeavour to examine these things in detail that are so puzzling to the practical iron-smelter.

In the first place, I find it to be a general belief amongst practical men, that their furnaces produce the largest casts, and that frequently the best or softest iron is produced in dry frosty weather; and on the contrary, that less iron is produced, and generally of the harder and inferior kinds, when the weather is warm and moist. This last, however, with regard to the quality being affected by these changes, is doubted by others; at all events I find it is not uniformly the case. One smelter informed me that he has sometimes observed his furnaces produce as good casts in the months of June or July, as they did in November or December, although he could assign no cause for it, if it was not from the drier state of the atmosphere on these particular days. Moisture, I find, is generally believed by the smelters to be the principal cause of deteriorating both the quantity and the quality of their casts, supposing that it acts by retarding the combustion, and thereby affects the heat of their furnaces; and so general is this belief, that various experiments have been tried, with the view of ascertaining and obviating these effects, by endeavouring to deprive the air of moisture previous to its entering the furnace, such as by surrounding the conducting pipe, which leads from the blowing cylinder to the air vault, with ice from an ice house, with the view of condensing the moisture, by reducing the temperature of the air. This experiment, however, must have been quite fallacious, notwithstanding the interior of the pipe became bedewed with moisture, and water trickled from it into the air vault; because, by reducing the temperature of the air, its bulk would likewise be diminished, and therefore a greater proportion of air would pass through the orifices of the tuyères into the furnace, which would be equivalent to an increase of their blast at the same time.

The introduction of fresh burnt lime, and of sulphuric acid, into the air vault, has likewise been proposed for the same purpose; but these substances could be of no practicable use, where such a body of air is to be acted upon.

Passing the air through hot iron pipes has likewise been suggested; but although this latter would increase the capacity of the air for an additional dose of moisture, it would not deprive it of what it already contained, while, from the expansion of volume by the heat, less air would pass through the tuyères; the blast would therefore be diminished in the oppo-

site ratio to the former experiment with the ice. This experiment must likewise have been unsatisfactory. Nay, so powerful, it is stated, are the effects of this agent, moisture, that when it is required to apply wet clay to make up the dam or the tuyères, the following cast is deteriorated. However, if that was the cause, would not the damp sand and wet clay used at the tap-hole destroy every cast? Even a change of wind from a cold dry north or east wind, to a bland moist wind from the south or the west, is believed to affect the products of the furnaces also. For the same reason several iron-smelters, to get rid of this moisture, have condemned the water-pressure altogether, and have substituted a regulating air-vessel in its stead; conceiving that as the air becomes hotter from compression, it will have a tendency to absorb, or at least to evaporate, and carry along with it more moisture by its contact with the water; while others, who still retain the water-pressure, affirm that nothing of the kind ever takes place in a well-constructed water-pressure, because a stratum of cold air always rests upon the surface of the water, which effectually prevents the stream of hot air from coming in contact with it at all; and that when the manhole door is removed, the water within is generally found covered with a pellicle of light dust, clearly showing that its surface is not agitated, or even so much as ruffled by the passing stream. Some smelters again are rather disposed to attribute these effects to moisture in the coke itself, knowing the great affinity that this substance has for absorbing moisture, especially as it is so frequently exposed on the coke hill during damp or wet weather. Now, there may be something in this after all—since the coke is always served out to the furnace by weight, more or less fuel will be put into the furnace in proportion to the weight of water it contains; but it surely cannot affect it in any other way, because the whole of the moisture must be driven off long before it leaves the top of the furnace, and so soon as it becomes red hot. Besides, we find as good iron produced by those smelters who make their coke in kilns, and quench, or rather drench it with water in the process of cooling, as by those whose fuel is taken hot from the coke hill. Neither am I aware, after all, that any material difference is perceived in the quantity or quality of the iron produced by the furnaces whose blast is regulated by the air-vault, the large iron receiver, or the regulating cylinder with the floating piston, any more than in those in which the water-pressure is employed.

For these reasons I am not inclined to believe that moisture has any connexion whatever with the changes observed, and, therefore, must look for other causes which may be more likely to affect the operations going on in the interior of the furnace.

This irregularity of the smelting furnace has long ago been ascribed to change of temperature also; because from the greater density of the air during frost, more air must necessarily be discharged into the furnace by the blowing cylinder, than when the air is expanded in volume during hot weather; and, therefore, to render the working of the furnaces as uniform as possible, various schemes have been devised to keep the air cool. In one work which I visited, I found that for this purpose the receiving valves of the blowing cylinder were connected with an old coal pit, which happened to be within a little distance of it. By this means the blast during summer was kept cool, as the whole of the air which supplied the cylinder was drawn from the old workings which now only communicated with the external air by another pit, which was situated on the opposite side of a valley. However, after all this trouble and expense, uniform products were not obtained; the iron being still found to vary in quality. This arrangement, however, instead of diminishing these irregularities, as was supposed, would have a tendency rather to increase them; because the effects produced by changes of temperature are frequently modified or counteracted altogether by the changes of volume produced by atmospheric pressure. This latter agent (atmospheric pressure) does not seem to have been taken into account at all; but I will now proceed to show that it also must exert a most material influence either to neutralize, modify, or increase, the effects of the former; and which, when combined with the effects of temperature, may account for the furnace sometimes driving fast, or producing more iron, on particular days, even in the summer months. Thus, the range of the barometer in this country being about 3 inches, or rather more than one-tenth of the mean pressure, this change of density alone would produce a difference of $\frac{1}{10}$ in the bulk of the air; and, therefore, if between a severe frost with the thermometer at 20 degrees, and sultry weather with the thermometer at 70, the difference would be 50 degrees; and as atmospheric air dilates or contracts a 485th part for every degree of Fahrenheit's scale, this difference of temperature would produce a difference of rather more than $\frac{1}{10}$ in the bulk of the air likewise. Now, if during that severe frost the barometer stood at 31 inches, while during the sultry weather (perhaps before a thunder storm,) the mercury had sunk to 28 inches, this also would produce a difference of rather more than another tenth. These two causes combined would alter the specific volume of the atmosphere, and, of course, the bulk of any given measure of air fully $\frac{1}{5}$th. Now, this irregularity in the supply of one of the elements of combustion would have precisely the same effect as an equal irregularity in the consumpt of the other element, or the fuel. Or, if a careless furnace-man, during the melting of one cast, was to use a weight of 90 pounds for weighing out the coke to the furnace, during other casts to use 95, 98, 107, 110, or 112 pounds, in place of the regular weight of 100 pounds of coke, we could hardly look for uniform products from his furnaces. Now, as the heat generated in the furnace in a given time is just in proportion to the quantity of fuel consumed, and since combustion can only take place by the union of the oxygen of the air with the fuel, therefore, if a greater quantity of air be blown into a furnace in a given time, a proportional quantity of fuel will also be consumed, and, of course, a greater degree of heat will be evolved, and a greater proportion of the ore reduced. And since the blast furnace is always kept full, or supplied with fresh materials as the charge sinks down, fully $\frac{1}{5}$ more would be required when the barometer was at 31 inches, and the thermometer at 20 degrees, than when the barometer was at 28 inches, and the thermometer at 70 degrees; or $\frac{1}{7}$ more when the temperature was at 30 degrees, and the barometer at $30\frac{1}{2}$ inches, than if the temperature was at 60 degrees, and the barometer at $28\frac{1}{2}$ inches; or, if we consider it in relation of time, fully $\frac{1}{5}$th more metal would be produced in the first, and $\frac{1}{7}$th more in the last case; or these 12 hour casts would have been equal to one of 14 hours 4 minutes in the first case, and 13 hours 7 minutes in the last, as compared with those when the barometer was at $28\frac{1}{2}$ inches, and the thermometer at 60 degrees. Now, if we attend to these ever varying proportions in the density of the atmosphere, we will not be at all surprised that a difference should be observed, both in the quantity and quality of the iron from the blast furnace. However, as calculating the compound action of the barometer and thermometer for this purpose would be attended with trouble, I thought of constructing an instrument, (on the principle of the old air thermometer of Amontous,) which of itself would indicate the effects of both pressure and temperature. Accordingly, as an experiment, I took a piece of old barometer tube about 15 inches in length, and having partly filled it with water, I inverted it, and allowed a little air to enter till I got just 12 inches of air into the tube, I then attached a small scale to it, divided into 100 parts of the whole length of the included column of air—of course one division would represent 1 per cent. more or less in bulk. Its action was so satisfactory that I was induced to make a more perfect instrument; the column of air in it being made exactly 12 inches in length when the barometer was at $29\frac{1}{2}$ inches, and the thermometer at 49 degrees, (being zero, or the mean of both pressure and temperature for Scotland,) this point is marked 100 on one of the scales, the other is divided into 12ths of an inch, which is equivalent to 5 minutes of time of the 12 hour casts. The tube of this instrument is formed like the fountain barometer, (see margin,) the liquid in it being dilute sulphuric acid, tinged red with lake. This instrument I afterwards placed in a northern exposure, and for several months kept a register of its motions: these observations were generally taken about 11 at night, and 9 in the morning. I shall, in the first place, therefore, give an example or two of the barometric

pressure, and the temperature, on some of these days, as each tended to affect the bulk of the air; and then show the combined effects of both as indicated by the little instrument, or blast-meter, (if I may so call it, as being a measurer of the blast); and afterwards, a table or copy of the observations as taken with this instrument, from the 23d January, to the 28th July, as indicating the absolute bulk or density of the air, and, of course, the supply of oxygen for combustion, in any given volume of air discharged into the furnaces during these six months. Example :—

| | January 23d. In. | Bulk. | Combined Bulk. | | January 24th. In. | Bulk. | Combined Bulk. | | January 25th. In. | Bulk. | Combined Bulk. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Day. | Bar. 28·7 | = 97 | 97 | Day. | Bar. 30·6 | = 104 | 108 | Day. | Bar. 30·1 | = 102 | 103 |
| | Ther. 50 | = 100 | | | Ther. 30 | = 104 | | | Ther. 44 | = 101 | |
| Night. | Bar. 29 | = 98 | 100 | Night. | Bar. 30·3 | = 103 | 105 | Night. | Bar. 29 3 | = 5 | 101 |
| | Ther. 45 | = 102 | | | Ther. 39 | = 102 | | | Ther. 42 | = 1·5 | |

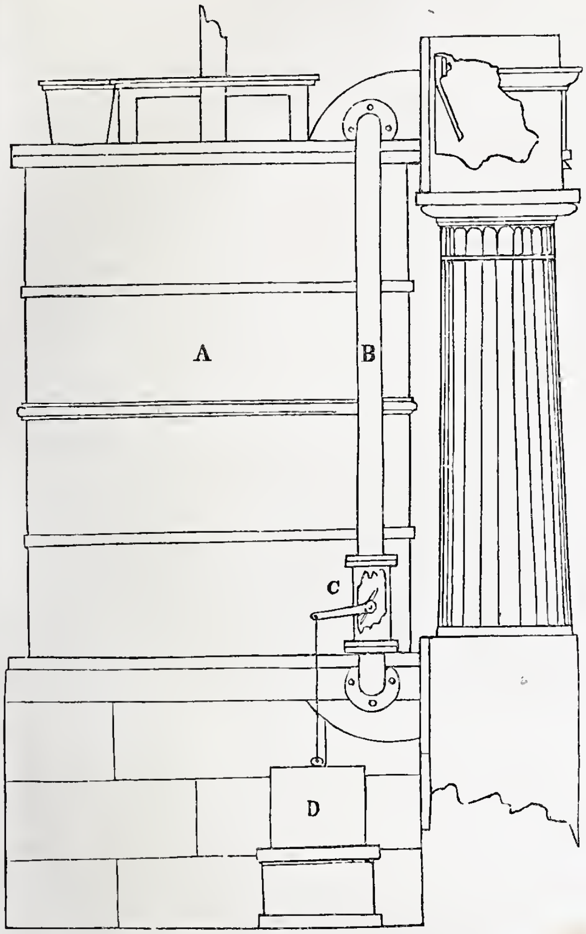
| | January. | | | February. | | | March. | | | April. | | | April. | | | May. | | | June. | | | July. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Day. | Night. | | Day. | Night. | | Day. | Night. | | Day. | Night. | | Day. | Night. | | Day. | Night. | | Day. | Night. | | Day. | Night. |
| 23 | 97 | 100 | 15 | 103 | 106 | 9 | 103 | 105 | 1 | 103 | 103 | 26 | 103 | 105 | 19 | 100 | 104 | 11 | 98 | 100 | 4 | 95 | 99 |
| 24 | 108 | 105 | 16 | 105 | 106 | 10 | 105 | 104 | 2 | 103 | 104 | 27 | 103 | 104 | 20 | 100 | 103 | 12 | 98 | 101 | 5 | 94 | 98 |
| 25 | 103 | 101 | 17 | 106 | 107 | 11 | 101 | 101 | 3 | 105 | 107 | 28 | 103 | 105 | 21 | 102 | 104 | 13 | 101 | 102 | 6 | 97 | 100 |
| 26 | 102 | 103 | 18 | 106 | 107 | 12 | 100 | 101 | 4 | 106 | '04 | 29 | 106 | 105 | 22 | 102 | 104 | 14 | 98 | 101 | 7 | 97 | 100 |
| 27 | 103 | 102 | 19 | 106 | 107 | 13 | 104 | 109 | 5 | 102 | 104 | 30 | 104 | 106 | 23 | 102 | 106 | 15 | 96 | 98 | 8 | 97 | 109 |
| 28 | 102 | 102 | 20 | 107 | 105 | 14 | 100 | 103 | 6 | 102 | 103 | | | | 24 | 102 | 104 | 16 | 97 | 101 | 9 | 98 | 100 |
| 29 | 102 | 102 | 21 | 104 | 103 | 15 | 102 | 103 | 7 | 101 | 103 | | May. | | 25 | 101 | 104 | 17 | 97 | 101 | 10 | 98 | 100 |
| 30 | 102 | 103 | 22 | 103 | 102 | 16 | 103 | 103 | 8 | 102 | 102 | 1 | 103 | 106 | 26 | 100 | 105 | 18 | 98 | 100 | 11 | 98 | 98 |
| 31 | 101 | 101 | 23 | 104 | 103 | 17 | 100 | 104 | 9 | 103 | 103 | 2 | 105 | 106 | 27 | 100 | 104 | 19 | 99 | 103 | 12 | 98 | 99 |
| | | | 24 | 104 | 103 | 18 | 103 | 103 | 10 | 103 | 104 | 3 | 104 | 105 | 28 | 101 | 105 | 20 | 100 | 100 | 13 | 98 | 100 |
| | February. | | 25 | 102 | 104 | 19 | 103 | 103 | 11 | 104 | 102 | 4 | 103 | 104 | 29 | 100 | 104 | 21 | 98 | 101 | 14 | 97 | 101 |
| 1 | 101 | 102 | 26 | 104 | 105 | 20 | 103 | 103 | 12 | 101 | 102 | 5 | 104 | 105 | 30 | 101 | 104 | 22 | 97 | 99 | 15 | 97 | 100 |
| 2 | 102 | 103 | 27 | 104 | 103 | 21 | 102 | 102 | 13 | 101 | 104 | 6 | 102 | 106 | 31 | 101 | 104 | 23 | 96 | 100 | 16 | 99 | 100 |
| 3 | 103 | 105 | 28 | 104 | 104 | 22 | 103 | 103 | 14 | 103 | 103 | 7 | 102 | 105 | | | | 24 | 98 | 100 | 17 | 99 | 102 |
| 4 | 105 | 107 | 29 | 104 | 103 | 23 | 102 | 101 | 15 | 101 | 103 | 8 | 104 | 105 | | June. | | 25 | 99 | 102 | 18 | 101 | 102 |
| 5 | 107 | 104 | | | | 24 | 101 | 101 | 16 | 102 | 105 | 9 | 100 | 105 | 1 | 101 | 104 | 26 | 99 | 102 | 19 | 99 | 101 |
| 6 | 103 | 104 | | March. | | 25 | 101 | 101 | 17 | 103 | 104 | 10 | 100 | 103 | 2 | 100 | 101 | 27 | 99 | 100 | 20 | 98 | 102 |
| 7 | 105 | 105 | 1 | 102 | 103 | 26 | 103 | 104 | 18 | 103 | 105 | 11 | 99 | 103 | 3 | 98 | 99 | 28 | 99 | 102 | 21 | 100 | 102 |
| 8 | 102 | 102 | 2 | 101 | 104 | 27 | 103 | 103 | 19 | 103 | 102 | 12 | 101 | 102 | 4 | 98 | 100 | 29 | 100 | 103 | 22 | 97 | 100 |
| 9 | 103 | 104 | 3 | 103 | 103 | 28 | 103 | 103 | 20 | 101 | 102 | 13 | 102 | 105 | 5 | 99 | 103 | 30 | 100 | 101 | 23 | 100 | 101 |
| 10 | 104 | 106 | 4 | 103 | 103 | 29 | 102 | 103 | 21 | 102 | 103 | 14 | 102 | 105 | 6 | 101 | 102 | | | | 24 | 99 | 101 |
| 11 | 106 | 104 | 5 | 103 | 103 | 30 | 103 | 102 | 22 | 102 | 104 | 15 | 103 | 104 | 7 | 100 | 102 | | July. | | 25 | 99 | 101 |
| 12 | 104 | 107 | 6 | 103 | 102 | 31 | 102 | 103 | 23 | 102 | 104 | 16 | 103 | 104 | 8 | 98 | 100 | 1 | 100 | 101 | 26 | 99 | 99 |
| 13 | 105 | 104 | 7 | 102 | 103 | | | | 24 | 104 | 103 | 17 | 101 | 104 | 9 | 99 | 100 | 2 | 96 | 100 | 27 | 99 | 99 |
| 14 | 104 | 103 | 8 | 104 | 104 | | | | 25 | 103 | 104 | 18 | 100 | 104 | 10 | 98 | 100 | 3 | 99 | 100 | 28 | 101 | 102 |

| Number of Casts, with the respective Proportions of Air to each Cast. | 1 | 2 | 3 | 10 | 18 | 21 | 40 | 41 | 49 | 76 | 55 | 26 | 15 | 8 | 1 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 94 | 95 | 96 | 97 | 98 | 99 | 100 | 101 | 102 | 103 | 104 | 105 | 106 | 107 | 108 | Per Cent. |
| And if in time equal to. | h. m. 11 15 | h. m. 11 23 | h. m. 11 30 | h. m. 11 37½ | h. m. 11 45 | h. m. 11 52½ | h. m. 12 0 | h. m. 12 7½ | h. m. 12 15 | h. m. 12 22 | h. m. 12 30 | h. m. 12 37½ | h. m. 12 45 | h. m. 12 52½ | h. m. 12 59½ | As the period of each cast. |

The above tables show what the supply of one of the elements of combustion was, during each cast, or 12 hours, (supposing that these observations had been taken regularly at 12 o'clock, or in the middle of each cast,) however, as it is, of all these casts, the one, on the 5th of July, had only 94 per cent. of air, instead of 100; therefore, only 94 per cent. of the proportion of coke could be consumed, which would be nearly the same in effect, as the furnace-man using 94lb. of coke instead of 100, as formerly noticed, (only with this difference that the air must always regulate the rate of consumpt of the fuel); while on the 24th of January, 108 per cent. of air was used, thus making a difference between these two casts, of 14 per cent. of air, or equal to one hour and three quarters in time. Therefore, while the blowing engine continues to work at her regular speed, for every 100 strokes which she makes, she will, to all appearance, be discharging the same quantities of air into the furnace, whether the liquor in the instrument is at 90, 100, or 110; but the real quantity of air discharged into the furnace in consequence of the alteration in its bulk will really be equal to 90, 100, or 110 strokes respectively, as indicated by the instrument. Now, suppose a furnace to require about 3000 cubic feet of air per minute, when the blast-meter is at 90, only about 2700 will be supplied; but when it is at 110, then the supply will be 3300 cubic feet, thus making an actual difference of $\frac{1}{5}$, or about 600 cubic feet per minute—an irregularity sufficient to account for the furnace sometimes driving fast, and sometimes slow—even the rate of combustion of air-furnaces must also be affected more or less from the same cause. This instrument might likewise be useful in ascertaining the supply of oxygen afforded to the lungs of animals in different states of the atmosphere, or in heated apartments, and may throw some additional light on respiration, or rather the starvation in the supply of vital air, as the cause of the squalid and sickly appearance of those employed in confined and heated atmospheres; but I shall leave this application of it to the physiologist.

Having thus traced the amount of this irregularity in the supply of the oxygen occasioned by atmospheric changes, I will now proceed to point out a means by which a uniform supply may be obtained at all times from the blowing machinery. Let A, (see figure in next page,) represent a blowing cylinder, capable of supplying three furnaces, or of blowing 6 tuyères of 3 inches diameter each: let the upper and lower ends of the cylinder be connected by a 4-inch pipe, B, in which is fitted a throttle valve c (as in the steam-engine); this valve must be connected with an air-vessel D, containing about 8 cubic feet of air, and suspended like a gasholder in a circular groove filled with mercury; these atmospheric changes likewise affecting the included air, would cause the air-vessel to rise or sink; which latter, could be so nicely adjusted, as to shut or open the valve, so as to allow the extra portion of the denser atmosphere to escape back to the other side of the piston, and to shut it off as the air became more expanded; by this means, the dilatation and contraction of the atmosphere would correct itself. However, there is still another source of irregularity, occasioned also by the barometric changes in the density of the air, when the power employed is the double-stroke condensing steam-engine, (as they are usually erected for working a blowing cylinder,) having neither fly-wheel nor governor to regulate their speed, and whose motion is only controlled by the resistance of the blast, and as the fire-man keeps up his steam to the regular pressure indicated by the steam-gauge, without having any reference whatever to the pressure of the air,

whether it can support 28 or 31 inches of mercury, and as the steam must always displace the atmosphere, to make room for itself, which in the latter case has become one-tenth heavier, therefore the difference of pressure upon the steam-loaded piston descending into a vacuum, will be one-tenth greater when the mercury in the barometer is at 31, than when it has sunk to 28




inches; and therefore, if a blowing-engine works to 40 horse-power, when the barometer is at 28 inches, it will work equal to a 44 horse, when the mercury is at 31 inches, and of course it will perform an additional number of strokes: to remedy this also, it will only be necessary to add a regulating bellows, such as were used to regulate the steam-engine, before the application of the rotatory pendulum; or a fly-wheel and governor might be added. Furnaces which are blown by water-power, notwithstanding that they may have an abundant supply during the summer months, will also be subject to the irregularities occasioned by the alteration of volume in their blast. However, these atmospheric changes being comparatively slow, will affect the quantity more than the quality of the iron, because the cementation will in all probability proceed as rapidly as any increase of temperature in the furnace from these causes, especially from the barometric changes. Now, since the power of the blowing-engine is increased by the same cause that diminishes the volume of the air, and if to this we add the effect of temperature, it being no uncommon thing for the mercury to be high in the time of frost, and low in warm and moist weather, or high in summer during a cold north or east wind, we need not be at all surprised that the iron-smelter should have ascribed the irregularities of his furnace to the moisture of the atmosphere, since the irregularities are so closely connected with the hygrometric state of the air.

Having thus shown the influence that atmospheric changes in the volume of the air must produce on the progress of combustion in the furnace, I shall now proceed to consider the construction of the furnace itself, and the effects which must be produced by introducing the supply of air in the manner commonly adopted in the iron-works of the present day.

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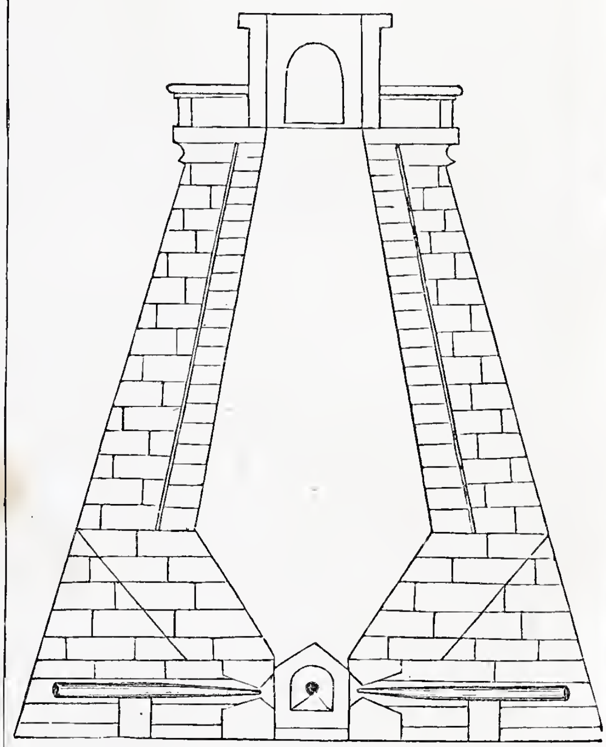
## CHAPTER II.

### ON THE FORM AND MANAGEMENT OF THE SMELTING FURNACE.

In last chapter I endeavoured to account for the irregularities in the quantity and quality of the iron produced by the smelting furnace, from the irregular supply of oxygen, occasioned by changes of temperature, and barometric pressure affecting the volume of the air; and shall now proceed to the investigation of other sources of irregularity, which I conceive must arise both from the particular form or construction of the furnaces at present in use for the purpose of smelting iron, and likewise from the manner in which the air is applied to the fuel in these furnaces. The blast furnaces at present in use are of various sizes, being from 35 to 60 feet in height, and at the boshes, or widest part, from 12 to 17 feet diameter. The general form is shown in Fig. 1.

*Fig.* 1.



From the boshes upward, they gradually decrease in width till they reach the tunnel-head, which varies from 7 to 9 feet diameter, according to the size of the furnace. The hearth, or lowest portion, for the reception of the metal, and the introduction of the blast, is generally a cube of from $2\frac{1}{2}$ to 3 feet square. The air is introduced by one, two, and sometimes by three small apertures called tuyères. When two tuyères only are used, the orifices of their blow-pipes are about 3 inches diameter, and the pressure of the blast is from $2\frac{1}{2}$ to 3 lbs. on the square inch; the velocity therefore that the air acquires, when it enters the furnace, is about $4\frac{1}{2}$ times greater than the most violent hurricane that ever blew. If we ask the iron-smelter the reason

for giving such a velocity to the air, he says, a sharp blast must be had in order to obtain the requisite degree of heat in the hearth, which is found necessary to melt the ore and flux, and likewise to make the air *force a passage* upward, through such a mass of material. Now I am not inclined to admit the necessity of either; because I find the velocity of a gentle gale of wind, or the draught from a chimney of 28 feet in height, quite sufficient to generate a degree of heat so intense,—even in the small air furnaces used in the manufacture of cast-steel—and of such a dazzling brightness, as to vie with the meridian sun itself in splendour; and which will not only melt the blister-steel, but if care be not taken, will quickly run the fire-clay crucible into slag also;—and as to the latter reason, the contents of a blast furnace are certainly of much too open a nature, materially to obstruct the passage upward of the stream of air that escaped so easily through the three-inch orifices of the two tuyère pipes, even although it should become expanded to twelve times its former volume, from the intensity of the heat. We must now direct our attention to the present form of the smelting furnace, and the nature of that operation by which the ore is reduced to the metallic state. In the early state of the arts, the furnaces used for the smelting of iron appear to have been, in general, very small, seldom exceeding in size the hearth of the present furnace. Some were only blown by the winds of heaven; while others were blown by streams of falling water, or manual labour. Early voyagers inform us, that in some of the South Sea Islands, the operation of smelting ore was thus performed by the native islanders, after they had excavated a small hollow in the earth, about one foot square, in an exposed situation on the brow of a hill. Around this hollow they built a very open wall of rough stones, from two to three feet in height, and about the same in width; this space they afterwards filled with brushwood and dried sea ware—then applied fire to it; and as the mass burned down, they continued to throw in fresh fuel, and along with it, small pieces of iron ore. The sea breeze blowing through the open spaces in the wall, produced a sufficient degree of heat to reduce the ore to the state of metal, which collected in the excavation below, and from which it was afterwards allowed to run out by means of a narrow channel left for that purpose. As soon as the metal began to fix, they broke it off, and commenced hammering it with stones,—it being then in a state of crude steel, and partly malleable.

Mungo Park likewise saw the natives, in the interior of Africa, smelting iron in a furnace of earth, about 6 feet high, and blowing it with bellows rudely formed of goats' skin. Many of the furnaces still used on the continent, particularly in Norway and Sweden, are not much larger than the founder's cupola, and are blown by currents of air produced from streams of falling water, or by wooden bellows. Even the furnaces used in Britain, prior to the substitution of pit coal, were of the same description. However, after the introduction of this new fuel, and from the slow combustibility of the coke from the pit coal—as compared with the charcoal of wood, which was formerly in use—the iron smelters found it necessary to increase the mass of ignited matter above, so as to make up by time for what they wanted in intensity of heat, which they formerly obtained from the more pure carbon of the wood charcoal. Accordingly, a sort of hopper mouth seems first to have been added, which afterward seems gradually to have been increased in height, till the furnaces of the present day have acquired the enormous height of fifty or sixty feet. The contracting of them, from the boshes upward, was probably as much for the purpose of concentrating the heat that was constantly ascending from the ignited matter beneath, as with the view of terminating them with a chimney. Be this as it may, the blast furnace of the present day seems to be nothing more than the old charcoal furnace, with a magazine of fuel and ore above; and is certainly not that form of furnace which modern science would have recommended, for the purpose of reducing the ore of such a combustible substance to the metallic state, and for operating with agents whose affinities are so nearly balanced, as oxygen, carbon, and iron.

To understand this subject properly, we must now turn our attention to the material to be operated upon, and carefully examine the progressive changes that the ore undergoes, until it is reduced to the state of cast-iron. If we attentively examine a mass of iron ore that has been roasted during windy weather, we will probably find amongst it pieces that have been subjected to various degrees of heat, and which may therefore furnish us with excellent specimens of all the progressive stages from the ore to the metal. Some may be obtained of a light red colour, that have hardly been red hot, while other pieces that have undergone the heat of a common open fire, will be of a dark red or purple. Others again, having been subjected to a cherry-red heat, may be found of an open spongy texture, from giving off gas; while those pieces that have been for some time under a bright cherry-red, will be found to have softened and sunk down into the crystalline form of the black oxide, and shooting forth small spicula or crystals, as if approaching the fibrous structure of malleable iron; while other masses may be found perfectly malleable,—other pieces, again, becoming of a more open texture, like blister-steel; while other specimens may be found with the appearance of having been in the act of melting, and presenting the granular appearance of a piece of cast iron that has been partially melted or disturbed, while cooling. Some ores are so subject to pass into the state of metal, when the process of roasting is carried too far, as to be a serious inconvenience,—becoming almost a solid mass of black oxide of iron, and blister-steel, so blended and run together as to require the aid of gunpowder to break them in pieces, before they can be removed to the furnace. I have had specimens apparently both in the state of malleable iron and blister-steel, taken from the centre of these masses, which were so perfectly malleable, that some of them were afterwards forged into nails. Now, if all these changes take place in the process of roasting ore in large masses on the hill in windy weather, this shows that a most intense heat, as is generally believed, is really not necessary for the reduction of iron ore to the state of metal, and that the changes going on in the smelting furnace are nothing more than a process of cementation. Again, if we only reflect on the nature of the operation for case-hardening iron, or what is better still, on the process pursued in the manufacture of blister-steel, there we find that when bars of malleable iron are imbedded in powdered charcoal, and kept for a few days in a strong red heat—about 70° of Wedgewood's scale—appearances like an amalgamation take place between the surface of the iron, and the carbon by which it is surrounded—at all events, the volatilized carbon penetrates even to the very centre of the bars of iron, forming them into carburet of iron; and this combination with the carbon is so rapid, that if not attended to, the iron will soon pass the point of saturation for steel, become cast-iron, and then melt into a mass—also the nice process of converting into steel, such delicate articles as wire gauze, fish hooks, &c., made of soft iron by surrounding them with the fine powdered borings of soft cast-iron, and subjecting the whole for a short period to a similar degree of heat—the process likewise pursued in the decarbonizing of articles of cast-iron, by rendering soft and even malleable the nails, horse shoes, knives and scissors, &c., made of that metal—likewise the method of decarbonizing the surfaces of steel plates, that are to be used for the purposes of engraving, by simply imbedding these articles in finely powdered iron ore, and subjecting the whole to a strong heat for a few hours, or the reconverting the surfaces of these plates again into steel, after they have been engraved, by stratifying them once more with charcoal powder. These processes show how feeble the affinities are, at that temperature, between carbon and iron; and how easily carbon penetrates, or diffuses itself, through ferruginous substances, when in contact, and raised to about 70° of Wedgewood's scale, or 1400° of Fahrenheit's; and therefore we may safely infer from the heat at the top of the blast furnace, that there cementation must commence, and that the ore must be converted first into malleable iron, then into steel, and lastly, by absorbing an additional dose of carbon, it will become cast-iron, melt, and then glide downward, along with the glassy matter of the flux, through the mass of strongly ignited coke beneath, where it will soon encounter another enemy which will arrest its progress before it reaches the bottom of the hearth;—and to that subject we must now direct our attention, namely, the still stronger affinity that both carbon and iron, under high temperatures, have for oxygen. The extreme rapidity with which iron at a bright red heat combines with the oxygen of the atmosphere, when undergoing the operation of forging on the anvil, is truly astonishing; but when large masses of iron, at a welding heat, are subjected to the blows of the anchor smith, or the tilt hammers of the forge, scales of black oxide are almost instantaneously formed; and, when detached and driven off by the action of the hammers, are again as instantaneously renewed upon the fresh exposed

surface of the metal. Now, if these brittle scales of black oxide be stratified with charcoal powder in a close crucible, and submitted to a similar degree of heat, the charcoal will soon deprive them again of their oxygen, and they will be once more restored to thin flexible plates of malleable iron; I even succeeded in the short space of two hours, with heat a bright cherry-red,—by means of a small crucible and animal charcoal—to restore thin scales of black oxide to the flexibility of wrought iron, while thin splinters of iron ore which I had also imbedded along with them only became black and spongy. But the affinity of malleable iron for oxygen is so strong, that although surrounded with coal in the forge fire, if the heat is carried too far, it becomes combustible, catches fire of itself, burns, blazes, and hisses, sending off coruscations and streams of fire in all directions. Even with iron at a good red heat, if a stream of air be directed upon its surface—as is sometimes done with forging small articles—combustion will go on, and the heat may by this means be continued or kept up, although at the expense of the iron itself. The tendency of cast iron likewise to combine with oxygen, is beautifully shown in the extreme inflammability of the fine dust of cast iron borings when thrown over the flame of a candle, or in the beautiful coruscations and showers of fire produced by the spray from the hot streams of iron issuing from the cupola, or the sparks of metal thrown off from the founders' ladles. These observations at once show the superior affinity that oxygen has over either the carbon or the iron, and how readily these latter substances dissolve their union—or cast-iron partnership, if I may so call it—to form new unions of their own with the oxygen of the atmosphere.

Now, could we conceive a more injudicious and unscientific plan, for the purpose of producing a highly carburetted or soft cast-iron than the form of the present blast furnace, where the new-formed metal, trickling in drops or small rills in its descent to the hearth, must fall into, mix with, and be dashed about by the violent tornado of fresh air from the blow-pipes? Part of it may be protected by the coke, or escape between the tuyères, or be cooled and oxidized, and, combining with the flux, melt into a brown glass; while part will catch fire, burn, and blaze with great violence, be reduced to vapour, and carried up with the stream of air, to be again deoxidized by its passage through the carbon in the upper region of the furnace, or to make its escape at the tunnel-head.

Before proceeding farther with the construction of the furnaces, I ought, in the first place, to direct attention to another subject, connected with the progress of combustion, and which, I think, will throw some additional light on this matter. About the year 1810, I had constructed a small furnace of about 7 inches diameter, by lining a sheet-iron cylinder with fire-clay; and as Dr Black had recommended, I put about an inch of charcoal, or rather fine sifted ashes from the smith's forge, between the fire-clay lining and the outer cylinder. I used a pair of small double bellows, and was endeavouring to melt copper in a crucible, for the purpose of casting a speculum. As the heat soon penetrated to the charcoal, and from there having been some coaly matter still left amongst it, smoke began to issue from the edges of the aperture for admitting the pipe of the bellows. With the view of making the blast carry in the smoke, I withdrew the pipe of the bellows just so far, that the current of air dragged in the smoke along with it. I soon observed the furnace, after this alteration of the pipe, becoming much hotter in the upper part than before. This change I attributed to the velocity of the blast,—like the water-blowing machine of the Germans,—carrying in an additional quantity of the atmospheric air along with it. I then varied the position of the pipe, and widened the aperture in the side of the furnace, till I obtained the greatest possible effect. Satisfied from these experiments, that a great velocity, or sharp blast,—as the founders call it—was of no use, I communicated the result of my experiments to the late Mr Robertson Buchanan, and also to the managers of two iron founderies, and advised them to try it on their cupolas. As an experiment, I widened the apertures of the tuyères in one of their cupolas, by simply removing the loam that they had been lined and contracted with, and then drew back the blow-pipes, which I fixed as far out as possible, without permitting any of the blast to escape. By this means the air was applied to a much larger surface of the fuel, and the result of this simple alteration was, that their furnaces became much more efficient, reducing the metal quicker, with less fuel, from the combination of the air being more perfect, and not brigging or choking up at the tuyères as formerly. These founders now became satisfied that the high pressure of $2\frac{1}{2}$ or 3lbs. on the inch, which they were using, was really not necessary, but actually bad. They therefore procured new blow-pipes of $2\frac{1}{2}$ inches diameter, in place of the former ones, whose orifices were only $1\frac{1}{4}$ inch diameter, to a blast cylinder of 24 inches; and by this means their engines were relieved of more than one-half of their former burden, and of course required less fuel for the boilers. The effect was so striking, even upon their cupolas, that I began to suspect the cold sharp blast which evidently produced the brigging, by cooling the slag and even part of the metal in its descent, might likewise tend to cool the fuel, and thus retard the combustion in the furnace.

To ascertain this, I began to observe narrowly the effects of the blast upon the open fire, by trying if I could actually cool down the fuel by blowing with my utmost force, and, at the same time, holding the pipe of the bellows as near as possible to the surface of the fuel, so as to prevent the stream of air spreading. When the fuel contained earthy matter, I soon produced blackness; but if I tried charcoal of wood, or the cinder of good soft coal, my utmost efforts only produced a more intense degree of heat, and an extreme degree of brightness, attended with a rapid combustion of the fuel. In prosecuting these experiments, my attention was attracted to the singular appearance of the rest of the fire, which had become of a dusky brown, as if choked; while I had just been urging it with the blast from a powerful bellows, which, under ordinary circumstances, would soon have had the whole in a blaze. I now perceived the true cause of the furnace heating better when I withdrew the pipe; because, while I held the pipe close to one piece of ignited fuel, the combustion was so rapid, and so complete, by the violence with which the air was driven against the ignited surface, that the greater part of the oxygen in the stream of air became saturated at this point; and this saturated stream of flame, and consumed air, spreading over the surface of the fire, obstructed the farther supply of fresh air, and thus retarded the consumption of the rest of the fuel. I then recollected that the same thing takes place in soldering with the blowpipe; the piece of peat or charcoal on which the article is supported, only consumes at the point where the stream of air and flame impinges upon it, while the rest of the surface, although covered over with flame, simply becomes red by the heat, but is not decomposed. By repeating and varying these experiments on different kinds of fuel, I became perfectly satisfied that if the fuel operated upon was pure carbonaceous matter, and contained no earthy substance which would form a crust on its surface to protect the carbon from the fresh supply of air, no velocity that I could impart to the blast could carry it so rapidly over the glowing surface of the combustible, as to abstract the heat without allowing time, for a part of the oxygen at least, to form a fresh combination with it, and by this means to continue the combustion. And here another thought presented itself to my mind. To supply a cupola or blast furnace with air, from one or two small orifices, cannot be so good as by a number of openings, or by such an arrangement as is obtained by the use of a grate or bars; because, in the first place, from the quantity of air which is required, the whole must be sent in with great velocity: hence, if the fuel be pure, the combustion and heat evolved must all be generated in one single focus or spot near the tuyères, and can only be carried upward through the rest of the fuel by means of the intensely heated azote and carbonic oxide; while, if the fuel be impure, obstructions will arise to the free application of the blast upon its surface, which will impede the combustion, and cause the furnace to work irregularly. And as the radiation and dispersion of heat are always in proportion to its intensity, so a greater part of the heat, generated in so small a space, must be dissipated and lost in the walls of the hearth, and lower parts of this furnace; while that portion of the blast, which does not come into immediate contact with the fuel, will be so rarefied by the violence of the heat, as to be incapable of farther combination with the fuel above this point.* Whereas, in the latter case, by a more gentle

* Repeated experiments have been made upon the gaseous products issuing from the tunnel-head, by thrusting a long iron pipe down into the charge, and collecting the air. In every case, I understand, free oxygen, or rather undecomposed air, was obtained, to the no small astonishment of the experimenters. However, when we consider that highly rarefied air is incapable of supporting combustion, and that even the most explosive mixture of the gases cannot be fired when too highly rarefied, it seems extremely probable, that the heat pro-

application of the air to the fuel, a much more perfect union must take place, and no obstructions will be formed; and from a much larger surface being acted upon, by uncontaminated air, the combustion must be much more diffused and perfect, as is the case in the reverberatory furnace, or in the small pit furnaces used for melting steel, from either of which a most intense heat can be obtained. In these furnaces, the air ascends between the bars of the grate on which the fuel rests, with no more velocity than that of a gentle breeze, or with a pressure of only one half, or one third, of an ounce upon the superficial inch; and as it enters in a number of thin streams, it is directly applied at the natural density of the atmosphere to the whole lower surface of the fuel. As the most intense heat is evolved just at the surface of the flame, or line of union between the gaseous combustible and the air, and as in this furnace the surface extends over the whole lower stratum of the fuel, an immense quantity of heat is thereby generated, which being carried upward with the intensely heated products of the combustion, becomes deposited in the mass of coke or fuel above, which, from the slow transmitting power of this substance, it is well enabled to retain. By this means it soon accumulates so as to become a magazine of heat, of a most intense and dazzling brightness, and without the body of fuel being decomposed, until it finally sinks down upon the grate to replace that which has been consumed.

Let us now attend to the working of the furnaces. We are told by the iron smelter, that the quality of his iron, and the profitable working of the furnaces, depend very much upon the management of the tuyères. What the workmen understand by the term tuyère, is a kind of conical tube, which is formed in the furnace by the glassy matter of the flux sliding past the orifices for the admission of the blast—the constant rush of cold air chills this mass of melting matter round the edges of these openings, and thus produces a sort of pipe or channel, extending more or less into the interior of the furnace. Sometimes they will become so strong, and project so far, as to meet together in the middle of the hearth—which very much obstructs the working of the furnace. Now, as the furnace is always found to be in the best working condition when the tuyères extend about half-way across the hearth, great care is taken, by the keeper, to prevent them from either melting off or extending farther, by means of increasing or diminishing the blast—sometimes on one side, sometimes on the other—or by altering the proportions at the tunnel-head; for when they happen to drop off from the side, it is as prejudicial to the working of the furnace as the opposite extreme.* "Sometimes this happens from adding an excess of ore, or 'mine,' as they call it in Wales, at the tunnel-head, which creates such an additional degree of heat in the hearth, as will not only melt off the tuyères, but will even injure the brick-work of the furnace itself. From the fierceness of the heat, the iron becomes thick on the hearth—the quality bad, and the quantity small.† To remedy this, more fuel and less ore must be used. *After a short time*, the effect of this change becomes apparent: new tuyères begin to form and extend inward, the sides of the furnace become cooler, and the quality of the iron improves." Now, how is this that the furnace becomes most effective when the blast is partially obstructed by these cones of slag? The reason is obvious. When the tuyères fall off, the blast is applied directly upon the surface of the fuel, by which means nearly double the quantity is consumed, because the whole of the oxygen combines with, or is taken up by the fuel; but when these obstructions exist, then only a portion of the dense air can come into direct contact with the surface of the fuel, while the remainder will become so rarefied by the violence of the heat in the hearth, and so mixed and contaminated by that which has already been decomposed, as to be rendered no longer fit for the purposes of combustion, or capable of forming any useful combination. If, therefore, the iron is of a better quality when one-third or one-half only of the fuel is consumed, then it is obvious that the ore is allowed to come too quickly down, when the combustion goes on so rapidly. From the obstructions being removed, their action, therefore, must just be the same as the reducing of the blast—so that the ore may be kept longer in a state of cementation; and, *vice versâ*, when the tuyères fall off, the increased energy of the combustion will bring down and melt the iron before it is sufficiently carbonized "When masses adhere to the sides of the furnace, called scaffolding, which sometimes takes place, they increase the burthen or proportion of ore—by this means the heat is again increased, and the scaffolding melted off; after this, the burden of ore is again reduced, and the furnace works regularly, as before. Still, notwithstanding all these precautions, the most experienced and steady workman is unable to keep the furnace uniformly in the most advantageous working state, as it will be sometimes driving fast, at other times slow, and without his being able to account for these changes that so frequently occur." But these tuyères of slag serve another purpose also, for they act as a shield or canopy to protect the falling metal from the stream of fresh air; for when these tuyères fall off, the portion of melted metal that falls on the inclined planes of the boshes will be collected, and conducted directly over their edges into the hearth—that part of it which falls through the stream of air will instantly be ignited, and blaze and burn as in a smith's forge—thereby creating such an additional heat, as even to melt and destroy the brick-work of the furnace itself. If such effects take place in consequence of the blast coming in contact with the melted iron—then why depend upon such a fragile shield as the slag, when it could be constructed of the materials of the furnace itself? Or why allow the blast to reach the metal at all, till the oxygen is saturated with the carbon? The oxidizing and reviving powers of the flame of the small blowpipe might teach the propriety of this.

These scaffoldings or dams that are sometimes formed by the melted material adhering to the sides, and which occasionally give way and bring down a great quantity of fluid iron along with them, likewise prove that the ore and flux are both melted considerably above the hearth.* The circumstance, too, of the whole of the contents of a furnace becoming one solid mass from the accidental stoppage of the blast, shows the same thing; and, also, that it is a regular process of cementation, going on from the tunnel-head until it becomes fluid metal. I have thus endeavoured to trace out the operations going on in the blast furnace, in order, if possible, to arrive at the true cause of the anomalies that are found to exist, and, if possible, to discover a means of remedying these. The result of my investigations has been my own conviction that moisture has very little to do with these changes; that temperature alone has much less influence than has generally been supposed, being so frequently neutralized by the barometric pressure; but that the effect of these two agents, sometimes acting together, must have a considerable influence on combustion, since the volume of the air is at times altered fully one-fifth in its bulk, as shown by the little instrument. But the great cause seems to be the present construction of the blast furnace,—the contracting of it at the top,—the retaining the present form of the hearth or small old furnace, and discharging the whole air necessary to supply the combustion of so large a furnace into so narrow a space, while all the melted matters must pass downward through this body of air previous to their reaching the bottom. And, considering the inflammable nature of iron at so high a temperature, the wonder is more at the quantity obtained than at what is lost. Another form of furnace has lately come into use, called the Cupola (Fig. 2). Great doubts, however, have been entertained about the economy of these erections, as, from the thinness of their sides at the boshes—being only 17 inches thick—the heat will be allowed to escape too freely; but, if my views of this matter be correct,

duced by that portion of the blast which comes into direct contact with the surface of the fuel, will so rarefy and expand the remainder as to render it incapable of any farther combination.

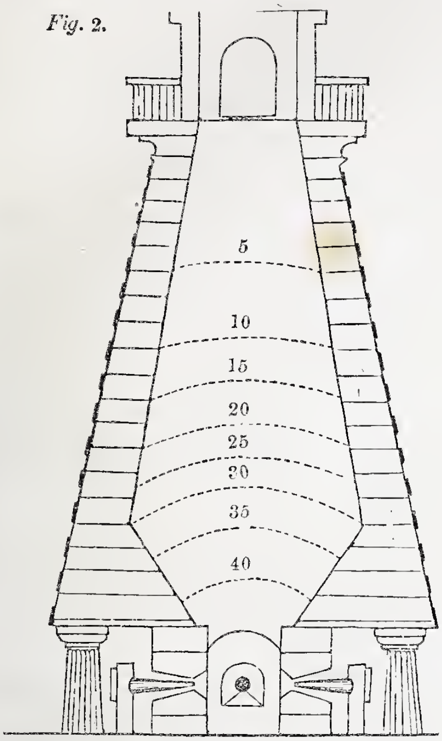
* The Welsh furnaces, from the nature of their ore and flux, have a great tendency to form these tuyères, or to choke up; and they are said to require nearly double the quantity of fuel to produce iron of the same quality, when the tuyères unfortunately melt or fall off.

† If the proportion of fuel be so small as to be consumed so fast that the metal comes within reach of the blast, while yet in the state of malleable iron—then, as the fiercest heat cannot render iron in this state fluid, and as it cannot escape the action of the blast by trickling down through the interstices of the coke, like the fluid cast-iron, and as welding iron is extremely inflammable—therefore, under such circumstances it must ignite, and blaze with great fierceness, until the whole is consumed. Hence the fierce heat and waste of materials, and hence the necessity of proportioning the quantity of fuel to the blast, to allow sufficient time for cementation, so that the metal may arrive at the state of fluid cast-iron before its comes within its influence. Hence also the reason for decreasing the proportion of fuel, and increasing the burthen of the ore, when they wish to increase the heat for the purpose of melting down the scaffolds, and, *vice versa*, when they wish to reduce the temperature of the furnace.

* I was glad to find in the report of the subsequent meeting of the British Association, that so distinguished a metallurgist, as Mr. Mushet is known to be, had arrived nearly at the same conclusion from practical experience, while I was only reasoning from the appearance of specimens which I had picked from the roasted ores, and from conversations with the smelters.

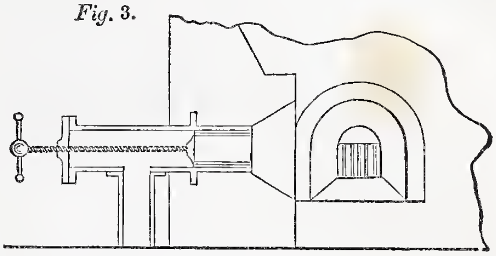
this escape of heat will be no disadvantage, as it will only keep

*Fig.* 2.




the melting point a little lower down in the furnace, and thus give the materials more time for cementation before they reach that region. To remedy these defects as far as possible, I should think the proper form for the furnace ought to be nearly that of the present blast furnace, inverted; the blast ought to be soft, and applied to as large a surface of the fuel as possible, either by means of wide tuyères; or grates might be formed of fire-tile from 3 to 4 inches thick, and from 14 to 18 inches square—each tile might have a $\frac{3}{8}$ inch projection at the ends, moulded upon them as other furnace bars, and the whole fitted into a cast-iron air chamber let partly into the brick work; this chamber to have sliding rods, passing through stuffings, to clear the grates with, and also to have a screw to push forward the tiles as they decay, as shown in Fig. 3,—the tuyères or grates to open into small-

*Fig.* 3.



arched recesses, from 12 to 14 inches deep, constructed in the brick-work of the furnaces, and, resembling the interior of the windows of the old Norman cathedrals. These arched openings are intended to serve the purpose of the tuyères of slag that form in the present furnaces; and, therefore, they must have a projecting band or pediment to conduct the fluid metal and slag down by their sides. The interior of the furnace might be either an inverted cone, an ellipse, a hyperbola, or a parabola,—the latter curve I think the best, (Figs. 4 and 5,)—and the openings from the tuyères to blow directly into or across the focus of this curve, which ought to be about four feet, and about 30 feet from the focus to the spring of the arch, where it would then be about 20 feet in width. The top of the furnace ought to be arched over, both for the purpose of retaining the heat, and for

*Fig.* 4.

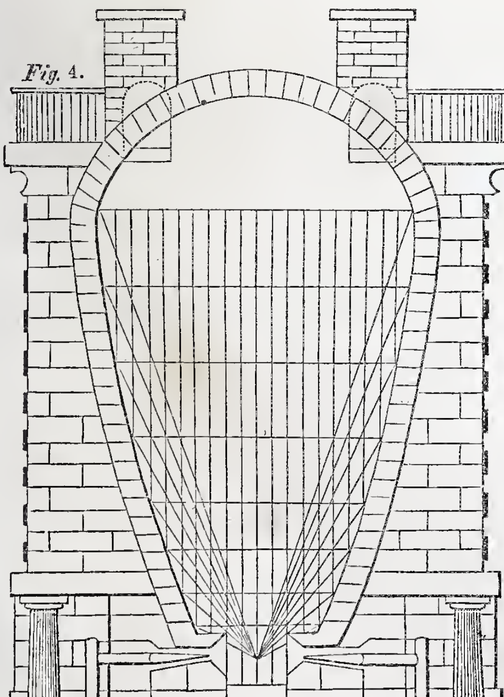
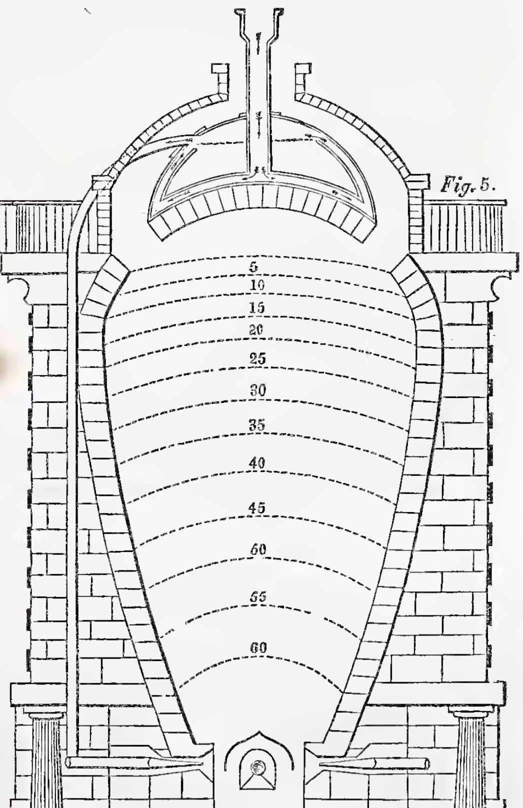


*Fig.* 5.



preventing the external air from consuming the fuel. The materials of the charge should be put in through hopper-mouthed openings in the haunches of the arch,—these mouths to have little vents or chimneys over each, as represented in Fig. 4. The charges of green coal and flux ought, therefore, always to be introduced first. and above them the ore,—by which means the ore will soon become sufficiently calcined by the flame from the coal, while the coal itself will be protected from the air; and, therefore, reduced to the state of coke without loss, thereby superseding the necessity of either roasting the ore or charring the coal; while, from the greater area of the furnace at the top, as compared with the present form, and the greater quantity of materials which it would contain,—although only melting at the rate of the present furnace, the charge would remain five times longer in the upper parts of this furnace. By this means much more heat would be absorbed from the flame, and the other gaseous products of the combustion, by their being kept longer in contact with the materials, and, therefore, the cementation would be much more perfectly effected—and, besides, more iron would be produced, and it would probably be of a better quality also; while, from the previous saturation of the oxygen with the carbon, in the lower part of the furnace, it would be prevented from combining with the new formed metal, or, in technical language, making the furnace burn. As all flame and extra heat that escape from the tunnel-head, above the temperature of the last-put-in materials, must be heat lost, therefore this furnace presents a means of economizing this also, which the common form of furnace does not do. This, however, I intend to make the subject of my next paper.

## DIFFERENTIAL MOVEMENTS.

*(Illustrated by Plate.)*

There are two views comprehended under each figure—a front and side view; and the same letters refer to the same parts in both views.

Fig. 1 is for transmitting a triple speed, by means of gearing. Applied by M. Caron, to the water-extractor.

*a*, the main shaft or driving spindle.
*b*, the driving pulley fixed upon the driving spindle.
*c*, belt for transmitting motion, and *c'* its guide.
*d*, a loose pulley carrying the belt *c*.
*e*, the spindle upon which is mounted the loose pulley *d*.
*f*, second pulley of the same diameter as pulley *d*, and fixed upon spindle *e*.
*g*, third pulley, having a socket, and working loose on spindle *e*.
*h*, fourth pulley, working loose on the socket of pulley *g*.
*i*, a pinion of 30 teeth fixed on spindle *e*.
*k*, a wheel of 41 teeth, fixed upon the socket of pulley *g*.
*l*, a wheel of 52 teeth, fixed upon the socket of pulley *h*.
*m*, a wheel of 52 teeth, driven by the pinion *i*.
*n*, a wheel of 41 teeth, driven by the wheel *k*.
*o*, a pinion of 30 teeth, driven by the wheel *l*.
*p*, the spindle upon which is fixed the wheels and pinion *m, n, o*. Now, suppose that the belt passes successively from one pulley upon the other, to *h*, it transmits to the spindle *p*, three different speeds in the direction of the teethed wheels, *i, m, k, n, l, o*.

Fig. 2, is for transmitting two speeds by gearing.

*a*, the main shaft or driving spindle.
*b*, a pulley fixed on the driving spindle *a*.
*c*, belt for transmitting motion.
*d*, a loose pulley, carrying the belt.
*e*, the spindle upon which is placed the loose pulley *d*.
*f*, a pulley of the same diameter as pulley *d*, and fixed on *e*.
*g*, a pulley with socket, same diameter as pulleys *d* and *f*, and running loose on the spindle *e*.
*h*, a wheel of 70 teeth, fixed upon the socket of the pulley *g*.
*i*, a wheel of 52 teeth driven by the wheel *h*.
*k*, the spindle upon which is fixed the wheel *i*.
*l*, a wheel of 70 teeth fixed also upon the spindle *k*.
*m*, a wheel of 52 teeth fixed upon the spindle *e*.
*n*, the belt guide.

When the belt *c* passes from the loose pulley *d* upon the fixed pulley *f*, it transmits motion from the driving spindle *a* to the spindle *k* by the intermediate wheels *m* and *l*; we thus obtain a simple speed; but if the belt pass to the pulley *g*, we then have by means of the wheel *h* and *i* upon the spindle *k*, a speed double of the first.

Fig. 3 is for transmitting two speeds by means of belts.

*a*, the driving spindle.
*b, b'*, two driving pulleys of different diameters fixed upon the spindle *a*.
*c*, an endless belt by which the slower speed is transmitted.
*d*, a similar belt by which the quicker speed is transmitted.
*e, f*, the belt guides.
*g*, a loose pulley carrying the belt *d*.
*h*, spindle of the pulley *g*, &c.
*i, k*, pulleys fixed upon the spindle *h*.
*l*, a loose pulley for carrying the belt *c*.

It is evident that when the belt *c* is placed upon the fixed pulley *k*, and the belt *d*, upon the loose pulley *g*, the speed of the spindle *h*, is less than when the belt *d* is upon the fixed pulley *i*, and the belt *c* upon the loose pulley *l*.

Fig. 4 is intended to transmit two speeds, of which one is a differential movement, applicable as double speed.

*a*, the driving spindle.
*b*, the driving pulley fixed upon the spindle *a*.
*c*, the belt, and *d*, the belt guide.
*e*, a loose pulley carrying the belt.
*f*, the common spindle.
*g*, a pulley of the same diameter as *e*, fixed upon the spindle *f*.
*h*, a bevel-wheel fixed upon the socket of the pulley *g*.
*i*, a loose pulley of the same diameter as the two others, and
*k*, a second bevel-wheel carried transversely by the pulley *i*, and gearing with the first, *h*.
*l*, a third bevel-wheel with a socket, of the same number of teeth as the first, *h*, gearing with the second, *k*, and moving freely upon the spindle *f*.
*m*, a curb adjusted tightly upon the socket of the wheel *l*, and weighted.
*n*, a ring fixed upon the spindle *f* for keeping the wheel *l* in its place.

As soon as the belt *c* passes off the loose pulley *e*, upon the fixed pulley *g*, it transmits to this last the speed which it receives from the driver *b*; but whenever it passes upon the pulley *i*, the spindle *f* turns with a double speed. It is proper to observe, that when the double speed commences, the curb *m* yields and allows the wheel *l* to slip a little. This is necessary to avoid the shock which would otherwise occur in changing the speeds instantaneously.

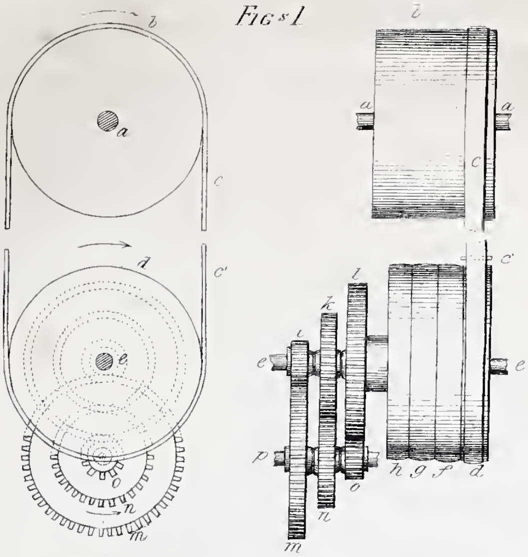
Fig. 5 is for the transmission of two speeds, of which one is a differential and variable movement.

*a*, the driving spindle; and
*b, b'*, two pulleys of different diameters, fixed upon the spindle *a*; *c* the belt for transmitting the slower and simple speed; and *d* its guide.
*n*, the belt for transmitting the accelerated speed.
*e*, a loose pulley enveloped by the belt *c*.
*f*, the common spindle.
*g*, a pulley of the same diameter as the pulley *e*, fixed upon *f*.
*h*, a bevel-wheel fixed upon the socket of the pulley *g*.
*i*, a third pulley of the same diameter as the two others, running loose upon *f*.
*k*, a bevel-wheel placed transversely, and carried by the pulley *i*.
*m*, a fourth pulley of the same diameter as the other three, and running loose upon *f*.
*l*, a bevel-wheel, like the first, *h*, placed upon the socket of the pulley *m*.

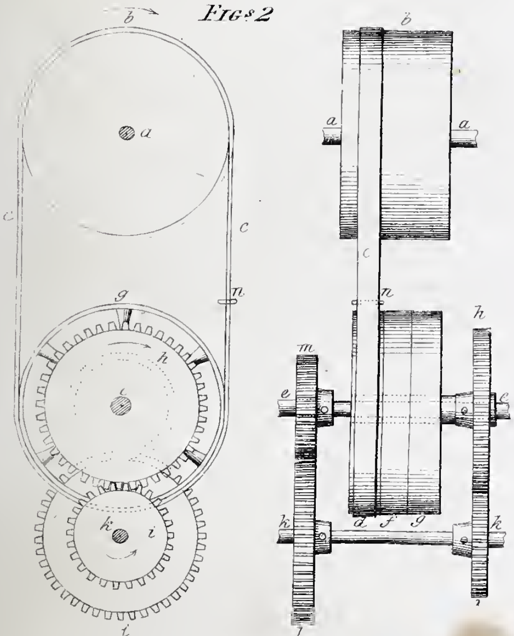
It will be observed that this arrangement has considerable analogy with that shown in fig. 4.; it differs, however, in this, that its quick speed may be varied, by more or less than the double of the first or simple speed; and also in the expedient of the second pulley *b'*, which transmits, through the belt *n*, a move-

DIFFERENTIAL MOVEMENTS.

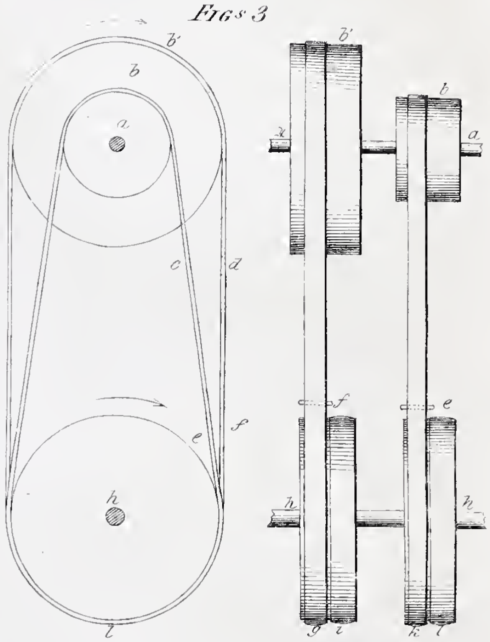
Figs 1



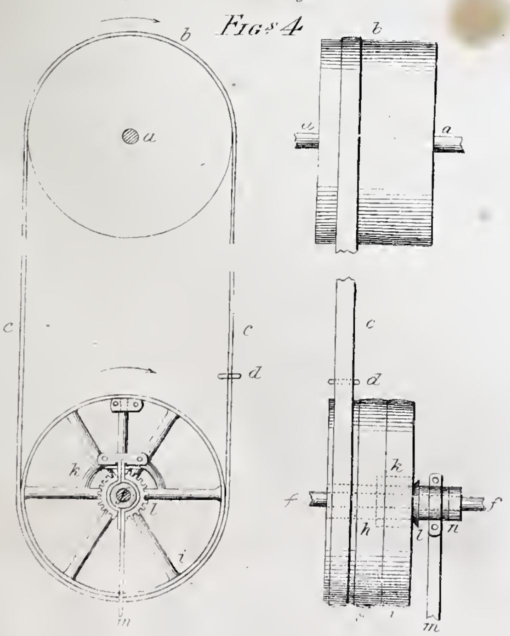
Figs 2



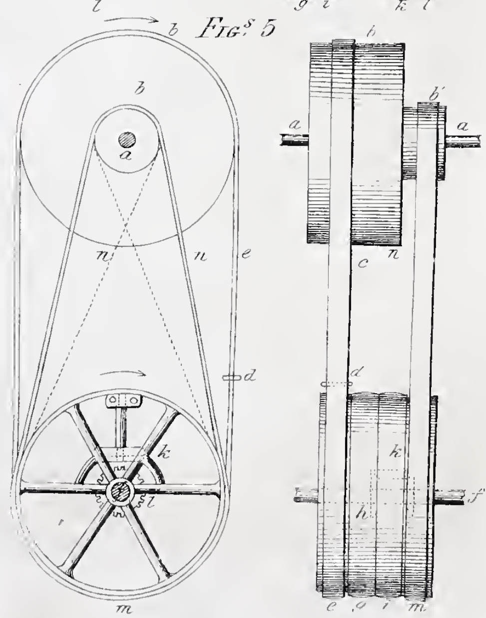
Figs 3



Figs 4



Figs 5



ment of rotation to the pulley *m*, and, by consequence to the bevel-wheel *l*, which is placed upon its socket.

Thus, the belt *c* being upon the pulley *i*, and supposing the bevel-wheel *l* (as in fig. 4) fixed, we perceive that the rotation of the spindle *f* is doubled in speed; but when the belt *n* has, in like manner, given to this bevel-wheel *l*, a movement of rotation in the same direction as that of the pulley *i*, this amount of rotation falls to be deducted from that of the spindle *f*. If, on the contrary, the belt be crossed, as seen at *n'* of fig. 5, and that the pulley *m*, and, at the same time, the wheel *l*, turns in the opposite direction, that rotation obviously falls to be added to that of the spindle *f*.

## ENGRAVING.

The arts by which representations of objects are given by impression, in one plain colour on paper, are commonly divided into three: Metal Engraving, Wood Engraving, and Lithography; and the impressions from the works executed in these arts, are respectively termed *plates*, *cuts*, and *prints*. We shall confine this paper to a description of metal and wood engraving, for, strictly speaking, lithography is not a species of engraving, or xylography, as it has been called by those desirous of pinning learned names to common practices. The earliest impression of an engraving on wood, which is known to be in existence, is dated 1423. It is a very rude representation of St. Christopher bearing the infant Christ on his shoulders, across a stream. Still, whatever its rudeness, it was produced by precisely the same process as the beautiful cuts which we now find illustrating books. The wood generally made use of for this purpose is box; the old workmen cut on the length of the wood, the moderns on the cross section. If a work of great finish was required, it was the practice to use two or more blocks. The first merely impressed the outline: another put in the half tints, and so on, until the requisite effect was produced. Some of Albert Dürer's engravings were worked by this tedious process. The tools requiredare four, namely, a graver, a tint tool, a gouge or scooper, and a flat chisel. It is pretty well known that all the parts of the wood are cut away except those intended to mark the paper, that is, all the lines we see in an impression are caused by elevation on the block. The mode usually pursued is this: the block is made perfectly even on the side on which the engraving is to be executed, and then a little powdered bath-brick, or some similar powder, is rubbed over it. The subject is drawn on the block with a pencil by the artist, who ought to possess a firm and correct handling, for it is not easy to correct mistakes. The cutting then commences, the wood left untouched by the pencil being removed, the cutter pushing his tools from him, whilst the metal engraver pulls them towards him. One of the best effects is caused by the processes called *overlaying* and *lowering*. In the former, where lightness of expression is desirable, the surface of the block is scraped away, so that the ink on those parts is only slightly received by the paper. In overlaying, pieces of paper or cloth are placed on the back of the block, and when the pressure is applied, the corresponding parts of the surface are more strongly pushed against the paper, the consequence being darker outlines or shades. A good deal of nicety is required in printing, and the effect of a wood-cut very greatly depends on the pressman employed. This remark applies, of course, only to such as are printed by hand presses; but the great majority of cuts are at present worked by steam from cylindrical machines. These are not so well adapted to the purpose, and impressions very often suffer a good deal in their appearance when the engraving itself is a good one. The greatest part of the work is done by the graver; the tint tool has a very thin blade and fine point; it is used in cutting parallel lines near one another, so as to produce an apparent depth of colour, as in the sky. The gouge is used in paring away masses of wood for which there is no use, at the edges, for instance. The block of wood is placed on a leather pad, stuffed with sand, and held firmly with the left hand, whilst the right is employed to move the tool. When the work has proceeded to an extent which makes the artist desirous of seeing its effect, he takes an impression on thin India paper with his hand, and then he is able to judge of the merit of his labour, and he can see whether he has made any mistakes that will mar the general effect of the cut. Engravers say that it is very difficult to correct a fault in the cutting, and they generally consider it the best policy to begin on a new block to attempting to alter the old one. Sometimes, when the fault is within a narrow compass, they ingeniously cut a piece right out of the wood, and insert another piece in its place.

Engraving on metal is a much more complicated process, and there is much greater diversity in it than in wood engraving. The most perfect kind is called Line engraving. Vasari tells us that the art of printing from engraved plates was the accidental discovery of Maso Finneguerra. He was a worker in niello, that is one of those goldsmiths of Italy, who traced designs, sometimes simple sometimes complex, on plates of silver or other metal, and then filled up the lines with sulphate of silver, a black substance. These lines were thus made to contrast with the rest of the plate, and something of the effect of our engraving on paper was produced. It is said that Finneguerra, desiring to see the effect of his work before going through the final process, that of filling in the black substance, applied a coloured fluid to the plate, and then took an impression on paper. Whether this simple process was first used by this particular goldsmith or not, certain it is that the earliest intimation of an engraving from metal is an impression of a niello plate by him. It was taken from a pax, (the vessel in which the consecrated bread was placed), which is still in existence at Florence, dated 1452, and in the Royal Library at Paris, may be seen the impression alluded to. There are thirty minute figures very beautifully designed, representing the Coronation of the Virgin. The steps by which the idea thus obtained was improved, do not appear, but not many years elapsed before we find persons whose occupation it was to engrave metal plates for the purpose of taking impressions on paper.

Before the artist applies his engraving tools to a plate of copper, it has to undergo a certain preparation. It is first hammered perfectly plain, and afterwards polished with pumice stone, then with a fine kind of slate, then with charcoal, and finally with oil rubber. The plate is next evenly covered with a thin coat of wax prepared with asphaltum and pitch. The design intended to be engraved is drawn on paper, the back of which is rubbed with red chalk dust. This being laid upon the varnish, the drawing is gone over with a fine point and thus the design is transferred. The paper being removed, the artist traces the outline through the wax upon the copper, and this having been done, the wax may be taken off. The effect of line engraving is produced, as the term imports, by a series of lines of different degrees of thickness and closeness, but without dots or other marks. It is now rarely used alone, but a good specimen is of high value. The chief study of the line engraver (says a writer on this subject) is to make such an arrangement of lines as shall mark the character of the various objects, whether they stand forward in bold relief or are mellowed by reflected or borrowed light, in short to convey to the eye the various gradations of colours which have been expressed by the artist on canvas, and finally to preserve the whole in its proper keeping or such a disposition of the various lights and shades (termed chiaroscuro) as shall leave no doubt as to the intended place of any object on the plate; for although the lights and shadows of nature are continually varying in direction and intensity throughout the day, still all objects preserve their relative value in the landscape. In giving smoothness and polish to any object, the lines are parallel and sharp, and clear in their course. To throw an object into the shade, and to give it a dull appearance, lines crossing each other perpendicularly are used, and are termed square hatchings, but where an intermediate state is required, the lozenge hatchings or lines crossing each other at an angle less than a right angle are employed. Where a waving or a flowing effect is to be produced, the hatchings will be slightly curved, but where an object is brought prominently into relief, various intervals in the shadings will produce the desired effect. Engraving with the dry point, as it is called, is executed by a sharply pointed needle which must have been carefully ground in a groove, to preserve its conical shape. The burr which the instrument raises has to be skilfully taken away afterwards. The dry point engraving is not often used without the help of other styles, but six pieces of Rembrandt are mentioned as being produced entirely by this method.

*Etching*, that is, corrosion, is now very generally used by artists. When the main lines of the design have been drawn through the wax upon the plate beneath, a little wall of wax is raised all round the plate and diluted nitric acid is poured into the trough. The acid instantly attacks those parts of the metal which have been acid bare by the needle, whilst the rest is effectually protected by the wax coating. The bubbles as they rise to the surface are taken off, and when it is conceived that the acid has bitten some parts deep enough it is poured off, and those places are covered by a preparation which resists the acid. The trough is again filled with acid in order that it may go deeper into the lines left unstop-

ped, and this process is repeated until the artist conceives that the chemical mixture has done its share of the work. As even a temperature as possible is preserved throughout, since it is found tho weather exercises great influence on the action of the acid. The wax coating is then removed, and impressions are taken from the plate in the usual way. This is a very expeditious mode of engraving, and it is calculated that during the time occupied by the old system in executing a plate, ten may be perfected by etching; at the same time it must be admitted that the results of the etching process are very uncertain. Steel is etched in exactly the same way except that a different chemical mixture is employed. Gilpin, in his essay on prints, describes the characteristics of engraving to be strength, that of etching, freedom. The resistance of the metal to the burin gives an air of formality to the lines; but the versatile thoughts of the artist are freely conveyed to the surface of the plate by the etching needle. Yet by the former method the strokes of the artist, deep or tender at his pleasure, can vary strength and faintness to any degree, and hence a power and a completeness which the other plan wants.

But the majority of good engravings are now executed by means of the preceding modes in combination. Thus an engraver commences with the acid, which is allowed merely to lay a foundation, and the general effect is brought about by the burin and the dry point. Those objects which require a jagged, broken or uneven outline, can be very well produced by etching, such as the trunks and foliage of trees, ruined buildings, rocks, &c. Sometimes the acid brings the design very nearly to a finished state, and the other tools add precision, strength, and the requisite sharpness by a few touches here and there.

Prince Rupert has usually had the credit of inventing mezzotinto, but other claimants have been put forward. The process is quite different from any of those previously mentioned. With an instrument called a *berceau*, consisting of a number of sharp points to which a handle is affixed, the surface of the plate is roughened and ploughed up in every direction. This is repeated many times until the plate is in such a state that if an impression were taken it would be one unvaried mass of black tint. This is the ground upon which the artist works with his scrapers and burnishers. With these he removes the burr which the berceau has raised wherever it is desirable to do so. The more these are employed the lighter the impression from those parts will be. Consequently the deep shades are left untouched, and the tools are only employed in those portions intended to be illuminated or to represent light objects. It will be observed that in the ordinary mode of engraving, the darker the shades, the more the tools and the acid are used; but here the tools are employed to recover particular portions of the plate from shade. The number of good impressions which a mezzotint plate will yield is very limited. In some respects mezzotint is superior in effect to any other kind of engraving, viz. where the utmost softness, mellowness, and richness are required; as in engravings from Rembrandt's pictures. On the other hand the lights are always defective, and there is a want of decision and energy. Etching is frequently employed to bite in the outlines, and when this is judiciously done, the excellencies of both styles produce a happy result.

The French have invented a style of engraving in imitation of chalk drawings. The plate is prepared as for etching, and the dotted effect of chalk on paper is obtained by a series of dots made through the wax by a fine pointed instrument. The acid is poured on, and the work finished by a constant series of dots made in the plate by tools of different sizes adapted to the character of the design. Such an exact facsimile of a chalk drawing has been made in this way that it has been found difficult to detect the difference. Of course the effect is only meagre and poor, and indeed it is a style not much patronised in this country, the good lithograph being much superior.

Aquatinta engraving is the result of an attempt to represent Indian ink or Sepia drawings. The subject is etched in after the usual manner, and solutions of aqua fortis are afterwards employed to produce the washy effects. It is a disagreeable style, and only employed where merely a general idea of objects is intended to be given. The shades are abrupt, and a slovenly appearance disfigures the whole.

Aquarilla engravings are an imitation of water coloured drawings. Here again etching is used to work the subject in, and as many plates are required as there are simple colours. Specimens of aquarilla engravings are not often seen; they are usually characterised by the same defects as those which pervade aquatints.

Lithography was not invented until the latter end of the last century, when a poor German musician, named Senefelder, desiring to print some of his compositions at a cheap rate, discovered the process which is now so extensively employed. The stone with which the art is practised is a kind of soft limestone, of which there are large quarries in the neighbourhood of the Danube. The surfaces of the slabs are rubbed smooth against one another, and pumice stone is called into requisition to add a greater smoothness. The sizes of the slabs vary according to the drawings intended to be placed upon them, but they are generally about two inches thick. The ink is composed of tallow, virgin wax, shellac, and common soap, in equal parts of two ounces each, and to these is added half an ounce of lamp black. When writing has to be done, instead of adopting the tedious plan of writing backwards, a thin sized paper is covered by a brush with a compound of French chalk, old plaster of Paris and starch, ground together with gum tragacanth, glue, gamboge and water. The writing is made upon this paper, which is afterwards placed on the stone. Pressure is applied and the paper being damped, is removed, whilst the writing adheres to the stone. For drawing, a lithographic chalk is prepared of the same materials, but in different proportions. If the method of transferring is not pursued, the usual way is to trace the subject on the stone with red chalk, and then lithographic chalk is passed over the lines. Weak nitric acid is then poured upon the stone to render the chalk lines insoluble in water, and that being washed away, gum water is applied to prevent the chalk lines from spreading. The stone is kept damp, and when the roller charged with printing ink is applied, only those parts which have received the lithographic chalk or ink, will take the printing ink, because that contains a quantity of greasy matter which the wet stone rejects. Paper being laid upon the slab, the whole is passed through a press, and an impression is immediately produced. Plates of zinc are now a good deal used as substitutes for the calcareous stone. The process is precisely the same, but the effect of lithography is considered superior to that of zincography.

## COMPOSITION USED IN WELDING CAST-STEEL.

Take 10 parts of borax, and 1 part of sal-ammoniac; grind them together roughly, and then fuse them in a metal-pot over a clean fire, taking care to continue the heat until all spume has disappeared from the surface. When the liquid appears clear, the composition is ready to be poured out to cool and concrete; afterwards being ground to a fine powder, it is ready for use.

## MINERALOGY.

### CHAPTER IV.

#### METALS.

Arsenic does not often occur as a native metal, but when it does so it is found in a granular form; arsenic artificially obtained has a steel grey colour, and a brilliancy of surface which it soon loses on exposure to air, and under these circumstances it gradually falls to powder; specific gravity 8·3. The artificial metal has a crystallised structure and is very brittle; a heat of 356° Fahr. is sufficient to volatise it without melting it. The peculiar odour it yields on being subjected to heat is often relied on as a test of its presence. The vapour condenses in small metallic crystals, which have a less density than the unsublimed mineral. Arsenic is a plentifully distributed mineral, and its poisonous qualities are well known. United to some other minerals among which are gold, silver, copper, and iron, it forms a compound named *Native Arsenic*, which has been found in Alsatia, Norway, Germany, and America. in massive and botryoidal shapes. Arsenic combines with oxygen in two proportions, one combination is named *arsenious acid*, the arsenic of the druggists, that occurs very rarely in nature; the other is called *arsenic acid*, found much more frequently. Indeed the *arseniates* form a numerous list of minerals, some of which have been already noticed. The native oxide of arsenic is found of a snow-white hue, varied occasionally by tinges of other colours. It has an earthy structure and has been found in

France and Germany. The salts of arsenious acid are termed *arseniates*. The *mineral green* of the painters is arseniate of copper; the arseniate of silver is a pure yellow colour frequently used to form corroborative evidence when it becomes necessary to prove the presence of the poisonous oxide. Arsenic combines with sulphur in four proportions, and two of the combinations are found in nature. The red sulphuret bears the name of *Realgar ;* it is found in many parts of Europe, sometimes crystallised, in which shape it becomes electric by friction. It is a brittle mineral without taste or smell, and insoluble in water. It has about 7 per cent. less sulphur than the yellow sulphuret commonly called *orpiment*, which is usually seen in thin flexible plates. It is insoluble in water and without smell. Specific gravity of Realgar 3·3, of orpiment 3·4. The two minerals are found together in many parts of the old and new worlds.

*Bismuth* when pure has a reddish white colour with a lamellated structure and considerable lustre. It is very brittle, fuses at a point between 462° and 497° Fahrenheit. One of its compounds with other metals has been found to melt below the boiling point. It volatises at a high temperature, if melted and slowly cooled it crystallises in cubes ; specific gravity 9·8. Its principal use is to form alloys and solders. The native metal has been found associated with other metals in Cornwall, Germany, France, Norway and America. *Sulphuret of Bismuth* is found native in various proportions. That called Bismuth Glance occurs in crystallised prisms as well as massive. It has a metallic lustre and a grey colour ; hardness 2 ; specific gravity 6·5. The sulphur forms about $18\frac{1}{2}$ per cent. A *carbonate of bismuth* is found in Cornwall.

*Antimony* is not often found pure in its native state. The metal is silvery white in colour, and has a laminated structure ; specific gravity about 6·5. It communicates its brittle quality to other metals. A 1000th part added to gold deprives that metal of its malleability and durability. It is principally used in making type metal, and some of the salts are employed medicinally. It melts at a red heat, and some chemists say that at a white heat it volatises and distils, which others deny. What is called *crude antimony* is a sulphuret, and it is found in many parts of the globe both massive and crystallised. The crystals are sometimes rhombic, sometimes circular. Its colour is lead-grey ; another variety is termed red antimony from its colour. *Oxide of Antimony* is found of a white colour in crystals as well as massive. It is soft, heavy, and translucent. The *antimonial ochre* of the Cornish mines is an oxide. Its colours are yellow and brown.

*Molybdenum* has not yet been discovered pure. When deprived of its impurities by chemical means it is found to have a greyish-white colour, and a specific gravity of 8·6. It can only be made to form a porous mass or a globule. The commonest ore is a sulphuret (*Molybdenite*) which occurs crystallised and massive, lead-grey in colour, opaque ; specific gravity 4·5. It contains about 40 per cent. of sulphur. The crystals are hexagonal. Their laminæ are flexible but not elastic. The blowpipe drives the sulphur away and the residue is powdery. It is found in Westmoreland, Cornwall, and in various parts of the continent. An *oxide of molybdenum* has been met with at Loch Crerum in Scotland, and in Norway and North America, but it is a rare mineral. Its colour is light yellow or green ; another combination of the metal and oxygen forms an acid.

*Tellurium* is a scarce metal of a silver white colour. It has a crystalline structure, is brittle and readily pulverises; specific gravity 6·1. It is a bad conductor of electricity, melts at a high temperature and can be made to burn in common air with a blue flame. The native metal is found massive and crystallised in small six sided prisms. It can be scratched by the carbonate of lime. Before the blowpipe it burns and volatises in a white vapour. Tellurium is found combined with several other metals. *Graphic Tellurium* an opaque mineral, with a metallic lustre, is a compound of gold, silver, and tellurium. *Yellow Tellurium* is a compound of the same metals with the addition of lead and a little sulphur. *Black Tellurium* was found on analysis to contain 54 per cent. of lead, a little copper, and a large quantity of sulphur. All these minerals occur crystallised, and their principal locality is Transylvania. An ore found in Norway, and named *Bismuthic Tellurium* contains 60 per cent. of bismuth.

*Tin*, a much more useful metal than any of those lately named has not been met with in a native state. The largest mines are those of Cornwall, but the purest ore is said to be found in Malacca. It was known to the ancients. Tin is soft, very malleable, and more tenacious than lead, a wire $\frac{1}{15}$th of an inch in diameter being capable of sustaining 31 lbs. It is flexible but not elastic ; specific gravity 7·2. It fuses at 442 Fahrenheit, and it will take fire if heated to whiteness, forming an oxide. It will crystallise if allowed to cool slowly from a state of fusion. Oxide of tin (*Tinstone*) occurs crystallised and massive in Cornwall and Saxony. Transparent, opaque, lustre vitreous. Colour black, red, brown, yellow and white ; hardness 6 to 7. Before the blowpipe it may be reduced to a metallic state. It will give out sparks on being struck by steel. There is a fibrous variety called *wood tin ;* the massive varieties are stream tin. Oxide of tin is only found amongst the primitive rocks. Oxygen forms about 21 per cent. of it. *Tin pyrites* is a sulphuret and is found massive and crystallised; colour steel-grey and yellow ; brittle ; hardness 3. It has only been discovered in Cornwall, and its constituents have been proved to be about 34 per cent. tin, and 37 per cent. copper, sulphur and a little iron making up the rest. The alloys of tin are numerous. It is a constituent of bell-metal, bronze, and pewter, alloyed with iron it forms tin-plate ; and the amalgamation of mercury and tin is used for the silvering of mirrors.

*Tungsten* has a steel-grey colour, and a specific gravity of 17·2. The native metal has not yet been discovered ; the pure metal is obtained from the acid which it makes when combined with oxygen. The substances called *Wolfram*, which is a tungstate of iron, and *Tungsten*, a tungstate of lime, are those from which the metal is obtained. The former is of a brown colour, and found crystallised and massive, the structure of the latter variety being lamellar, Germany and Bohemia are the places where it is met with. The tungstate of lime occurs in primitive rocks in Cornwall and on the continent. It is translucent and of a grey colour. An oxide of Tungsten has been discovered in North America.

*Titanium* when pure is of a bright copper colour, has a specific gravity of 5·3, crystallises in cubes, and requires a very high temperature to melt it. Most of the acids do not act upon it. Like the preceding metal it forms an acid when combined with oxygen ; and the mineral called *Rutile* is almost pure Titanic acid. It is met with in crystallised masses of a red colour, sometimes yellow, transparent, and opaque ; primary form a square prism ; specific gravity 4·3. Slender crystals are frequently found in quartz It has been met with in Perthshire, Switzerland, Bohemia, and North and South America. Titanium forms about 66 per cent. of rutile. The mineral *Anatase* or Octohedrite is an oxide of Titanium, found in acute octohedral crystals, the primary form of which is a square prism ; colour brown or blue, translucent ; electrical with friction ; specific gravity 4·8. Found in Cornwall and at various places on the continent. Titanic acid is frequently found combined with iron, and the minerals called Kibdelophan, Ilmenite, Crichtonite, and Mohsite, are supposed to be titaniates of iron, but they have not been completely analysed. Another Titaniate of iron called Iserine, has been found in the Scottish river Don, and

in the Mersey. *Sphene* is a silico-titaniate, and has been found near Ben Nevis, and in the Shetlands.

*Cerium* is with difficulty obtainable in its pure state. It is of a chocolate or rose-red colour, is pulverulent, and has so strong an affinity for oxygen that it decomposes water. Its principal ores have been named *Cerite, Cerine* and *Allanite.* The first is chiefly made up of silica and an oxide of the metal. It has been found in Sweden; is amorphous, is usually of a dull-red colour, with a resinous lustre, almost opaque. Cerine contains a large proportion of oxide of iron and some alumina and lime: it is nearly black, with a slight metallic lustre. Allanite has been found in Greenland both massive and crystallised, brown-black in colour, opaque; hardness 6. Iron, alumina, and lime, form large proportions of this mineral also. The mineral *Orthite* contains about 19½ per cent. of cerium. It is found in seams in felspathee rocks in Sweden. It contains yttria and manganese in addition to the matters named above.

*Uranium* has never been found as a native metal; it is of a red-brown hue, is brittle, and has a specific gravity of 6. *Uranite* is a phosphate, and occurs in the primitive rocks of Cornwall and in France, in thin lamellar plates or crystallised. It is of an emerald-green colour with shades of yellow. An oxide is sometimes formed along with it of a grey colour.

*Columbrium* was first discovered in North America, but it has been since found in Sweden. The pure metal is only obtained with great difficulty. It is a black powder, with a specific gravity of 6. *Columbite* is an oxide of a black colour, occurring crystallised and massive. It contains iron and manganese, but columbrium is present to the extent of 80 per cent. Oxygen forms an acid with this metal, called Columbic Acid.

*Cobalt* has a reddish, grey colour, a slight metallic lustre, and a specific gravity of 7·8. It fuses at about the same temperature as iron, and crystallises on cooling into cubes. It is a useful metal. It is employed to give a blue colour to glass and porcelain: under the name of smalt or powder-blue it gives a blue tinge to linen and writing paper; and the phosphate is used in the paint called Cobalt Blue. The metal has not been met with in its native state. The principal ores contain arsenic. *White Cobalt* is found crystallised and massive. It has a metallic lustre, with a silvery white hue. Specific gravity 6; hardness 5·5. The primary form of the crystal is a cube. It has been found in Cornwall, Norway, and Sweden. It contains about 50 per cent. of arsenic *Hard White Cobalt* contains rather less arsenic, but sulphur constitutes 20 per cent. When crystallised it is in the shape of cubes and octohedrons. Lustre metallic. Specific gravity 7. Found in Norway and Cornwall. *Grey Cobalt* is found in Saxony. It does not differ very much in hardness and specific gravity from the last named mineral. Colour greyish white. *Earthy Cobalt,* found in Cheshire and Cornwall, has a specific gravity of 2·4· Colours yellow, brown, and greyish black. The *Sulphuret of Cobalt* found in Sweden, contains about 38 per cent. of sulphur and no arsenic. *Cobalt Bloom* is an arseniate of Cobalt, found massive and crystallised, of various shades of red in Scotland, Cornwall, Bohemia, &c. Specific gravity 2·9; arsenic acid 37 per cent. *Red Vitriol* is a sulphate of Cobalt. It has a pale red colour; is found stalactitic and investing other minerals. It dissolves in water.

*Chromium,* never yet found native, is a brittle metal of a grey white hue. Specific gravity 5·5. Heat and acids scarcely act upon it. Oxide of Chromium is used to impart a green colour to glass and porcelain. Combined with oxygen in a certain proportion it forms an acid, some of the salts of which are employed in making pigments. The *chromate of lead,* called red lead, is found in Siberia and Brazil, both massive and crystallised. It is of a deep orange red colour. Specific gravity 6; hardness 2·5. Chromic acid constitutes about 31 per cent. The chromate of lead and copper has received the name of *Vauquelimite Lead,* the lead forming about 60 per cent., and copper 10. The *chromate of iron* has been found in Scotland, France, and North America. It is opaque, has a black colour, and when crystallised the primary form is the regular octahedron.

*Nickel* has a yellowish white colour. Specific gravity 8·2. It is ductile, malleable, and is one of the few metals affected by the magnet. It is a little inferior to iron in point of hardness, and requires a very high temperature to melt it. It is used to some extent at present in forming German silver, and its oxide is employed to give a green tint to glass and porcelain. It occurs native in a few places. The *arsenuret* is found crystallised and in other shapes, having a yellowish red colour. Hardness 5; specific gravity 7·6. Opaque. It contains slight quantities of iron, lead, and sulphur, as well as arsenic. It has been found in Cornwall and other places in Europe. The *sulphuret* is found in hexagonal capillary crystals of a yellow or grey colour. It is brittle, opaque, and has a metallic lustre. Sulphur forms about 34 per cent. The mineral called *Nickel-glance* is of a lead grey colour. It is a sulpho-arsenuret, and found in Sweden and and other places. *Pimelite* is an arseniate of nickel. It has a dull earthy appearance, green in colour, is found investing other minerals in Sweden, and the Harz. Analysis has detected a little magnesia and alumina, with 35 per cent. of silica in its composition.

*Zinc* seems to be more and more employed every day in the useful arts. It has a bluish grey colour. It is ductile and malleable, but has not much tenacity. Specific gravity 7. Zinc blende is a sulphuret found in Cornwall, Durham, and in Scotland. It occurs massive and crystallised of a brown and yellow colour. The *oxide* is found in North America in various shades of red, massive, and disseminated. Specific gravity 6·2. Brittle and translucent. *Calomine* is a carbonate of zinc, occurring in limestone beds in Durham, Derbyshire, and Somersetshire. It is met with crystallised in acute rhomboids, and then it is green in colour, or compact and earthy, and then the colour is yellowish brown.

*Cadmium,* a metal not discovered until 1818, has the colour of tin, is soft and crystallised in octohedrons. Specific gravity 8·6. It possesses the property of ductility and malleability to a considerable degree. It occurs in very small quantities, and always with the ores of other metals. It is found principally along with zinc.

*Lead* has a bluish grey colour; is soft, ductile, and flexible. Specific gravity 11·4. A wire $\frac{1}{10}$th of an inch in diameter will support no more than 30 lbs., so that its tenacity is not very great. It melts at 612° Fahr., and if cold, slowly crystallises in octohedrons. No degree of heat has been found to drive it off in the form of vapour. If cut with a knife a surface of great brilliancy is laid bare, but it absorbs oxygen from the air, and soon tarnishes. The uses of lead are so well known that it would be a waste of time to say anything on that head. It is a matter of doubt whether it occurs as a native metal. When found pure it has always been near a volcano or lead mine. The sulphuret of lead (*galena*) is a very common ore. It occurs both massive and crystallised, of a dark grey colour, a bright metallic lustre. Hardness 2·5; specific gravity 7·5. The sulphur amounts to about 13 per cent. Silver is frequently associated with it. It is found in Cornwall, Durham, Derbyshire, and Scotland. Two oxides of lead are found. One called *Native Massicot,* is of a yellow colour; the other, *Native Red Lead* or *Minium,* is of a red colour. The latter is found in Yorkshire, Siberia, &c. Both of these oxides are readily fused by the blow-pipe. Carbonate of lead is of a yel-

lowish colour, occurring crystallised and massive. Primary form of crystal, a right rhombic prism. Hardness 3. The crystals are transparent, and possess the power of double refraction. Specific gravity 6·3. Carbonic acid forms about 15 per cent. *Anglesite* is the name given by some to sulphate of lead. It is found in Cornwall and Anglesey, both massive and crystallised. Generally transparent and without colour, but sometimes tinged with several. The acid forms about 24 per cent. Phosphate of lead has been named *Pyromorphite;* it is usually met with in hexagonal prisms of various shades of brown, yellow, and green. *Cotunnite* is muriate (or chloride) of lead, has been found in small crystals in Cornwall, and in the neighbourhood of Vesuvius. Chlorine constitutes about 25½ per cent. Another muriate has received the name of *Berzelite.* It occurs in crystallised masses in company with an ore of manganese. An ore has been found in the Harz made up of selenium of lead; hence chemists name it Seliniuret of Lead. *Gorlandite* is an arseniate of lead met with in Cornwall. The crystals are yellow, and in shape hexagonal prisms. *Carinthite* is a *molybdenate, i.e.* a combination of molybdic acid and lead. There are several other ores of lead which, being of unfrequent occurrence, need not receive particular mention.

We have now gone through the second great division of minerals and pass to the last.

Class III.—Inflammable Minerals.

In this division the *Diamond* deserves the first place. Wonderful as it may seem, it is a fact that this precious stone is nearly pure carbon, of which matter charcoal is the best known representative. The inflammable nature of the diamond has been proved by placing it in the focus of a powerful lens when the whole has been dissipated by the heat. The diamond is always found crystallised; it is extremely hard, and generally without colour, but sometimes pervaded by tinges of yellow or blue. It is never found in large masses, and what are called large diamonds are only, comparatively speaking, large. There are several famous diamonds in the world, the value of which is calculated in hundreds of thousands of pounds.

*Amber* is another mineral used as an ornament. It is usually of a yellow colour; is highly electrical when rubbed. It has a specific gravity of about 1·065. It melts at 448° Fahr. It is composed of 80 per cent. carbon, and the rest is made up of hydrogen and oxygen, with a little silica, lime, and alumina, which constitute the residium when amber is burnt. Pieces of from 12 to 18 lbs. weight has sometimes been found, but it generally occurs in small pieces. It is thrown up by the sea on the coast of Prussia in large quantities.

*Sulphur* is one of the elementary substances of nature, for it has never yet been found to consist of other matters. It is an abundant mineral. Specific gravity 3. It is insoluble in water; it volatises readily; its fusing point is 232° Fahr. Native sulphur is found massive and crystallised. The transparent crystals are double refractive. It is very brittle; the massive varieties are found in large beds or masses in Switzerland in the salt deposits. In Hungary and Swabia it is found in veins. Of volcanic sulphur there is a large quantity near Naples, from which a good deal is brought to this island. It occurs more or less in the neighbourhood of all volcanoes. Sulphur forms with oxygen that powerful acid called Sulphuric. From what has been already said, it will be seen that it unites with most ores.

*Bitumen* has three principal varieties. *Earthy* bitumen has a dark brown colour, and is soft. It burns with a clear flame. It is found amongst other places in Cornwall, where also *compact bitumen* is met with. It has pretty nearly the same colour as the preceding, but is of closer texture; is brittle, and resinous in its appearance. It sinks in water. *Elastic bitumen,* called also mineral caoutchouc, is a soft and elastic substance, burning readily and emitting much smoke.

*Petroleum* (rock oil) has the consistence of tar, is of a reddish colour, and has a disagreeable smell. It burns with much smoke. It is found near Edinburgh, in Lancashire, and very plentifully in Persia.

*Naptha* is a yellowish coloured fluid much used in chemical experiments to envelope minerals which it is desirable to prevent oxygen coming in contact with, for naptha contains none of that gas. It burns with a bright flame. It has been found in many parts of the world.

Under the term *Coal,* is comprehended a variety of minerals from which this country has derived a large share of its commercial importance. It will, however, be unnecessary to give any detailed description of them since they are so well known. The immense coal deposits of England and Wales are believed to be vast masses of vegetable matter indurated and blackened by pressure and heat. *Jet,* used as an ornament, is a species of coal. It burns with a green flame, and a bituminous odour.

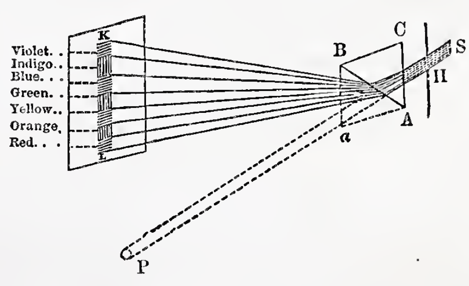
## NATURAL PHILOSOPHY AND CHEMISTRY.

### CHAPTER X.

DECOMPOSITION OF LIGHT—COLOURED REFRACTION.

We have already pointed out one remarkable effect which is produced upon a ray of light when it is made to pass through a triangular glass prism. But the bending of the ray from its direct course is not the only important fact observable in the experiment. There is another, which is, at least, equally extraordinary, and, in some respects, even better adapted to exalt our admiration of the harmonies of nature. This fact is that upon which the phenomena of colours depend, and which, in connexion with the admirable adaptation of our organs of vision, produces in the mind much of that pleasure which is associated with the faculty of *sight.*

The impression which naturally arises in the mind, when the eye surveys the extended landscape, or examines the many-coloured objects that fall within its nearer range, is, that light itself is a homogeneous and simple element, and that the colours reside in the bodies which reflect them. This is an error into which our senses lead us; but it is an error which no process of *à priori* reasoning could possibly have corrected; and had not experiment come to our aid, we would still have been ignorant of that world of study which the analysis of a ray of solar light lays open to us. This analysis is readily exhibited, and, indeed is present in every




coloured object upon which the eye rests. To take a direct experiment: suppose that a beam of solar light is admitted into a darkened room through an aperture, H, in a window shutter, and

that it is made to pass through a prism of glass, A B C, with one of its angles downward, instead of being refracted altogether, and appearing still as white light, which it does when the refracting surfaces are parallel—it is divided into several rays, and illuminates with different colours, an oblong space of a white card, K L, placed to retain it. If we examine this oblong image with a little attention, we observe that it is distinguishable into seven coloured bands, in the following order :—violet, indigo, blue, green, yellow, orange, red. These are the seven *prismatic colours ;* and the oblong image which they form is known, in scientific language, as the *solar* or *prismatic spectrum.*

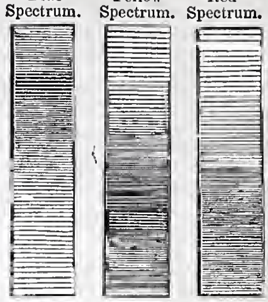
To show the spectrum distinctly, the screen must be placed at such a distance from the prism that the length of the space illuminated shall be, at least, double its breadth ; and this breadth is equal to the diameter of the round white image, P, which would be formed by the stream of admitted light, were the prism removed. The spectrum is indeed made up of a series of solar images, of different colours. These overlapping each other, produce a long band, in which the colours blend into each other, as seen in the rainbow. The order of succession is invariable, and depends upon the unequal refrangibility of the different coloured rays of which the composed white ray is made up. Thus the red ray deviates least from the direct path S P ; and the violet ray, most ; and the intermediate rays have intermediate degrees of refrangibility—the orange is thrown farther from the direct path than the red, and the indigo deviates less than the violet ; and hence we speak of the violet end as the most refrangible, and the red as the least refrangible end of the spectrum.

This unequal refrangibility is not an accidental circumstance : it is a property inherent in the several rays, which no subsequent refraction can alter. This is shown in a very simple manner. Supposing the spectrum to be received upon a screen, with a small opening ; if behind this opening we place a second prism, and make the coloured rays successively to pass through it—which is readily done by a little dexterous management of the first prism—they will be refracted by the second prism placed to receive them, and exactly in the same order as before : the violet will fall highest upon the second screen ; the indigo, a little lower ; the blue, lower still ; and so on down to the red, which will fall at the bottom, as in the first experiment.*

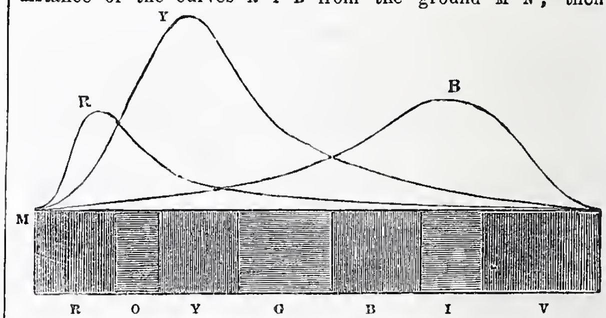
This inequality of refrangibility is not only true of the seven different colours which we have distinguished in the spectrum, but also of different rays of the same colour. For instance, if we divide the red band of the spectrum into three portions, and subject them to the same experimental examination as we proposed for the seven primary rays, we shall observe that the *extreme red* is less refrangible than the middle ray (the *mean red*), and this last, than the ray taken at the orange end of the red. The same is the case with all the rays throughout the whole length of the spectrum, from the extreme red to the extreme violet. This gradually increasing refrangibility has given rise to the opinion, that there are in white light an infinity of different colours ; and, in fact, if we observe with care any one of the coloured compartments in the spectrum, we perceive that it is made up of many tints ; and, as we pass through the whole length of the spectrum, there is a continual change of tint in the successive stripes.

To examine the circumstances a little more minutely, it may be observed, that of the seven prismatic colours which we have named, there are four which cannot be considered as simple lights : these are orange, green, indigo, and violet, which are formed by the mixing of rays of two different colours having the same refrangibility. Thus orange is formed by the superposing extremes of the red and yellow ; green, of the yellow and blue ; and indigo and violet, of blue with different proportions of red. The prismatic colours are, therefore, really reducible to three primary colours—blue, yellow, and red ; and, in fact, these lights spread over every portion of the spectrum. They are not, however, distributed in equal proportions—for if they were, the spectrum would be white, and we could have no decomposition of light by refraction—but each predominates in a particular part—the blue rays near the top of the spectrum ; the yellow rays somewhat below the middle ; and the red rays near the bottom. Thus, although there are blue rays of every degree of refrangibility, yet the larger proportion of them have a refrangibility greater than is possessed by the larger proportion of the rays of either of the other two colours ; and hence they are collected at the upper extremity of the spectrum. The reverse is true of the red rays ; and hence the majority of them are thrown to the opposite extremity, whilst the great proportion of the yellow rays, having a mean refrangibility, occupy the centre. In every portion of the spectrum there is, therefore, mixed blue, yellow, and red ; but where these simple lights prevail, the colours of the spectrum are produced ; and where two are present in excess over the quantities which form white light, the secondary colours, orange, green, indigo, and violet, are formed. All the conditions of the compound spectrum are, indeed, produced by the superposition of the three simple spectra, the distribution of the rays of which we have supposed to be represented in the annexed figures.

Blue Spectrum. Yellow Spectrum. Red Spectrum.



The effect of this combination of the simple spectra may be still further represented to the eye. Let the intensity of the primary colours, red, yellow, and blue, be represented by the distance of the curves R Y B from the ground M N ; then




where the red rises beyond the yellow and blue, the red space of the spectrum is produced ; where the curve of the yellow light prevails, the space is coloured yellow ; and, similarly, when the curve of the blue light is greatest, we have the blue space of the spectrum. Again, at the point where the curves of the red and yellow meet, the tint is orange ; where the yellow and blue are equal, the colour produced is green ; and where the red and blue are both in excess over the intermediate yellow, indigo and violet are produced. The numerical proportions in which these rays exist in the spectrum, and in white light, are expressed in the following table :—

| White. | Red. | Orange. | Yellow. | Green. | Blue. | Indigo. | Violet. |
|---|---|---|---|---|---|---|---|
| $R_{20} Y_{30} B_{50}$ | $R_8$ | $R_7\ Y_7$ | $Y_8$ | $Y_{10}\ B_{10}$ | $Y_6 B_{12}$ | $B_{12}$ | $B_{16}\ R_5$ |

It has already been observed, that the coloured bands of the spectrum are unvarying in the order of their succession ; but from this we are not to conclude that they are likewise of the same uniform and unvarying width. On the contrary, the length of the spectrum, and the space occupied by each colour, vary with the nature of the refractive substance of which the prism is composed, according to what is termed its *dispersive power ;* and different bodies possess very different powers of dispersion. For instance, if we make a hollow prism of plates of glass, and fill it with oil of cassia, we shall find that the spectrum which it produces will be more than twice longer than that formed by a prism of solid glass. The effect is equally remarkable upon the individual prismatic rays. Thus, when we compare the spectrum produced by oil of cassia with that produced by sulphuric acid, we observe that the least refrangible rays, red, orange, and yellow, occupy less space in the former than in the latter ; whereas the most refrangible rays, blue, indigo, and violet, occupy larger

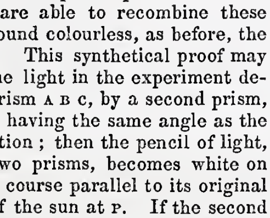
* The following are the indices of refraction of the different coloured rays:—

| | Red. | Orange. | Yellow. | Green. | Blue. | Indigo. | Violet. |
|---|---|---|---|---|---|---|---|
| Flint Glass,... | 1·6297 | 1·6297 | 1·6350 | 1·6420 | 1·6483 | 1·6603 | 1·6711 |
| Crown Glass, . | 1·5268 | 1·5268 | 1·5296 | 1·5330 | 1·6360 | 1·5417 | 1·5466 |
| Water,......... | 1·3317 | 1·3317 | 1·3336 | 1·3358 | 1·3378 | 1·3413 | 1·3442 |

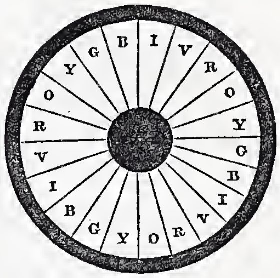
spaces. Even the dispersive power of dense flint-glass, and that of the lighter crown-glass, differ very considerably, and hence the possibility of adjusting two prisms of these substances together in such a manner that the dispersion produced by the one shall be neutralized by that produced by the other—leaving, at the same time, a considerable refractive power unobliterated. This is contrary to the opinion expressed by Sir Isaac Newton, whose dictum, in this instance, had the effect of retarding for a long time the perfection of optical instruments. He supposed that dispersion and refraction were always proportional, and, therefore, concluded that as all refracted light must, of necessity, become coloured in proportion to the amount of that refraction, a perfect telescope of refraction could never be made. Opticians, however, subsequently discovered the important fact that the quality of merely bending a ray of light—that is, *refraction;* and that of dividing it into different rays—that is, *dispersion*, are distinct qualities, and have not a uniform proportion to each other in different substances. Dolland was the first to take advantage of this discovery, and apply it to the construction of lenses, in which the iris of colour, observed to surround the image of an object seen in the common telescope, is wanting. These are called *achromatic lenses*, on account of this peculiarity, and are composed of two kinds of glass—flint and crown-glass—in which the refractive and dispersive powers are so related, that white light is transmitted under high refraction. It is, therefore, to Mr Dolland that we are indebted for the achromatic telescope, which Newton thought it impossible to construct.

This fact of *achromatism* (destruction of colour) is, indeed, an additional evidence that light is not a simple but a highly complex phenomenon. The resolution of the stream of white light into its coloured rays, by means of the prism, places before us the analytic proof; but when we are able to recombine these rays, and find the resulting compound colourless, as before, the evidence becomes more complete. This synthetical proof may be had by simply intercepting the light in the experiment described, as it passes through the prism A B C, by a second prism, *a* A B, of the same substance, and having the same angle as the first, but placed in an inverted position; then the pencil of light, which is coloured between the two prisms, becomes white on leaving the second, and pursuing a course parallel to its original course, will give a round image of the sun at P. If the second prism be made with large faces, it may be placed at some distance from the first, so as to receive a completely formed and obvious spectrum, and with precisely the same result. This form of the experiment shows very distinctly that there does not exist in a prism any peculiar property by which the transmitted light can have colour communicated to it, and that the only explanation which presents itself of the phenomena observed, is contained in the circumstance that a white ray of light is compounded of three coloured rays of unequal refrangibility.

A refined objection may, however, be stated in connexion with this explanation. If the rays have different degrees of refrangibility, and as all transparent substances refract light, when made to pass through them obliquely, it might be argued that we ought to have coloured light in general, and white light only as the exception. The simplest case which this objection offers is that of a beam of light passing obliquely through a plate of glass, by which it is refracted and decomposed. Let the plate be represented by A B, and let the extreme rays of the stream of light, incident on its upper surface, be denoted by P *p*, and P′ *p*′; then the ray P *p* is decomposed into its three elementary rays, and these being incident at different angles upon the second surface, will pass out separately to E. Similarly the ray P′ *p*′ will be decomposed, and its three coloured rays will pass to E′. Now, were these positively single rays of light, we would, undoubtedly, find the prismatic colours at E and E′; but, however small a stream of light we may take, it is made up of innumerable single rays; and, consequently, any ray, P′ *p*′, infinitely close, and parallel to P *p*, will give its coloured pencil *r*′ *b*′ E′ infinitely close and parallel to the coloured pencil *r b* E; so that, in the infinity of rays which are incident on a surface, there will be one whose blue, *b* E, exactly coincides with the red, *r*′ E′; and another whose yellow will exactly coincide with it; and thus the emerging light will be recomposed, and appear to have suffered no alteration in its passage through the glass. The extreme rays are not, indeed, completely recompounded, but the colours are too feeble to be detected. The same explanation applies to the transmission of the sun's light through the atmosphere, and, indeed, through all media having *practically* parallel surfaces.



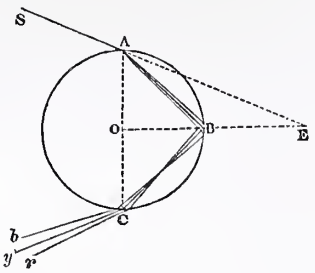

The conception, then, to which we are led is, that the phenomenon of white light consists of impressions made simultaneously upon the eye, by the lights of the different colours of which we find it made up; for we are not to suppose that there is any chemical action among the rays, by which their colours are obliterated. The whole effect is mechanical; and could we pound glass of the several colours sufficiently fine, and commingle the particles with sufficient accuracy, we might expect to obtain a mixture, which would appear white to the eye, although compounded of red, yellow, and blue ingredients. This may, indeed, be verified, in some measure, by a very simple experiment. If we take a circular disc, like that on the margin, about a foot in diameter, having a small circle at its centre, and a zone round its circumference, painted black; and if we paint the spaces R, O, Y, G, B, I, V, with colours which imitate, as near as may be, the colours of the spectrum—and then make the disc revolve rapidly on a central axis—the eye loses the sensation of the individual colours, and a white, more or less pure according to the greater or less accuracy of our colouring, is produced—leaving no doubt that if we had colours as perfect as those of the pure solar light, and proportioned our segments with sufficient care, their reunion would, like it, form pure white. The explanation of this phenomenon is very simple. Suppose we had but one red strip on a black ground, the eye would perceive, during the rotation, only a red circle, exactly as when a lighted stick is whirled rapidly round. Similarly, if there were only a yellow segment, the whole disc would appear yellow; and a blue segment would, in like manner, make it appear blue. Now, by having the three segments, red, yellow, and blue, we have presented to the eye, at the same instant, and in the same place, circles of these colours, and, consequently, a white circle—the sensation of white being the simultaneous sensation of these colours. We have supposed the compound colours, orange, green, indigo, and violet, to be used along with the three primary colours, to make up, in some measure, for the deficiency in the colouring which must ever attend such an experiment.




The fact of the decomposition of light under refraction, explains, in connexion with the laws of reflexion, all those lively coloured phenomena observed in our atmosphere under certain of its meteorological conditions. The vivid colours which gild the path of the rising and setting sun—the brilliant tints and sombre hues which contrast with the fantastic and changing forms of the sluggish cloud—the halos—the mock suns, and mock moons, which, in the days of ignorance, were looked upon with dismay, as the symbols of coming evil—of destruction and of desolation—the downfal of empires, and the death of sovereigns—all these we now look upon, with interest, as natural and beautiful illustrations of the relation of light to the masses of vapour which the solar beams traverse in their passage through our atmosphere to the earth's surface. One of the most beautiful and common of these appearances, deserves particular investigation, as it carries in its individual explanation an indirect explanation of all that class of phenomena depending upon the different refrangibility of the rays of solar light. This appearance is the rainbow, so inexplicable to the ancients, and which, though now well understood, continues to be the subject of admiration to the peasant and the philosopher.

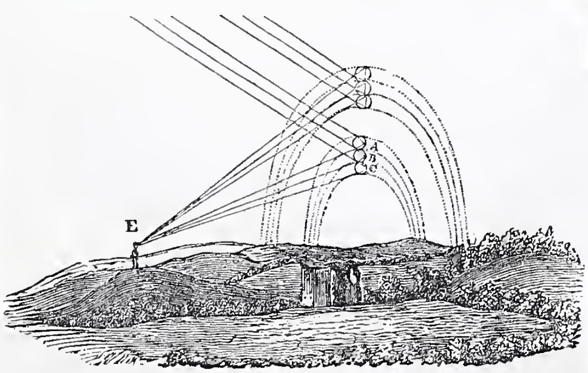
As every one has observed, the rainbow is seen when rain, which is falling in drops in front of the spectator, is strongly illuminated by the sun directly behind his back. The coloured arch may thus be considered as a portion of the base of a cone whose summit is the eye, and whose axis, if produced, would pass directly through the centre of the sun. These facts—and they are invariable—lead us at once to consider whether the rays

of light experience any modification from the drops of rain; and, presuming upon our knowledge of the effect which a transparent sphere has upon light passing into it—the drops of rain being regarded as perfect spheres—we conclude that there must be a refraction at the surface of each drop, reflection in its interior, and refraction again on emergence of the light. To understand this more distinctly—suppose a white ray, R A, to be incident in a darkened room on a globe of water, A B C; the ray will not go on to E, but be refracted in the direction A B to B; the angle of incidence, A B O, may be such that the ray cannot emerge, but will suffer total reflection (as formerly explained at p. 258,) in the direction B C. At the point C, however, we may suppose that it can emerge, and then it will be refracted in the directions C *r y b*, and if received on a screen at *r y b*, will give a prismatic spectrum.




It is very evident that such may be the course of a solar ray incident on any sphere, and, therefore, on a spherical drop of rain. But it is further obvious that the light will suffer refraction at the first surface A, and will then be resolved into its prismatic rays, and these will reach B at different angles, since their refrangibilities are different: the red ray will fall above B; the blue, below B; and the yellow ray, which we may take as the centre of the spectrum, will fall upon it. Each of these colours will be reflected according to the general law; consequently, supposing the centre of the second spectrum at C, the red ray will fall below, and the blue ray above it; and passing out under a second refraction, the rays will preserve their relative order; the red ray taking the direction C *r*; the yellow, C *y*; and the blue, C *b*. These rays being divergent, will not give a *distinct* spectrum; for, in order that a distinct perception of the colours may exist at any distance, the emergent pencil must be parallel. It must, however, be borne in mind, that, in practice, we do not consider individual rays: innumerable quantities of them enter the globe, and under the particular angles requisite; and of all these there are a sufficient number which have the necessary angles of incidence to pass, by refraction, reflection, and a second refraction, in lines sufficiently parallel to produce a coloured spectrum complete in all its parts. This is exactly what happens when a globe of water is held above our heads with the sun behind us: we see a spectrum in which the red is lowest and the violet uppermost.

To apply these conditions to the explanation of the rainbow, it is very evident, that if the spectator's eye be placed in the direction *r* C, he will distinguish only the red colour; if in the direction *y* C, the yellow colour; and if in the direction *b* C, the blue colour; but as in a shower of rain there are drops at all heights and all distances, all those which are in a certain position, with respect to the spectator, will reflect the red rays; all those in the next proper position will give yellow rays; and those in the next station, blue rays: these, as already explained, furnish all the other colours observed in the bow. To avoid confusion; suppose there are three drops of rain, A B C, and three




colours, red, yellow, and blue. These colours are refracted under fixed and determined angles: the red rays at an angle of 42 degrees (nearly), the blue rays at an angle of 40 degrees, and the yellow rays at an angle intermediate. Supposing, then, that the positions of the drops are such, that rays passing from them to the spectator's eye correspond to these angles, the drop A will send red rays; the drop B, yellow rays; and the drop C, blue rays. Further, all the drops which answer to these conditions—the appropriate angular position with respect to the sun and the eye—will, similarly, contribute rays of these colours. But all drops on the surface of a cone whose vertical angle is of the proper value have the required position, and, accordingly they, and they alone, reflect rays to the eye, of the particular colour corresponding to that position. Thus the rainbow is a series of spectra overlying one another, and each colour consisting of an indefinite number of rays whose refrangibilities differ from each other precisely as in the prismatic spectrum. This further explains the inferiority of those rainbows which are produced by artificial means—as that reflected from the spray of a waterfall, or under confined circumstances—as when rain falls between us and the side of a mountain; the number of drops is limited, and, consequently, the intensity of the spectrum is proportionally less than when the bow is projected on the wide vault of heaven. The height of the arch varies, moreover, with the altitude of the sun and the position of the observer—that is, the higher the sun the lower the arch; and, on the other hand, a completely circular rainbow is sometimes visible when the sun is sinking towards the horizon, and a shower is falling on the brow of an opposite hill. This phenomenon has also been observed under different circumstances; the observer being placed on the elevated brow of a hilly ridge overlooking a valley, in which a dense shower is falling, he may observe, with the sun behind him, a horizontal circular rainbow painted, as it were, on the ground below. Rainbows may also be produced by the reflection of the solar beams from the surface of a lake or river; and Mr Edwards describes one, which must have been formed by the exhalations from the city of London.

When the sun is strong, and the circumstances are favourable, a second, or even a third bow, may sometimes be observed, embracing the primary bow. The principles explained fully account for this phenomenon; but it must be noticed, that in this case, the reflected rays come to us in an inverted order—the red is the lowest band of the arch, and the violet the highest. This is explained by the fact, that the rays which form the secondary bow are incident on the upper side of the drops, and emerge parallel after *two* internal refractions and reflections. This bow is also fainter, because, the rain-drops being transparent, a part of the light is transmitted, and, consequently, lost at each reflection. The tertiary bow, which is formed by three internal reflections, is rarely visible. Occasionally lunar-bows are seen—but the colours are always exceedingly faint, and only appear under extremely favourable circumstances,

In high latitudes, where the air is commonly loaded with frozen particles, the sun and moon usually appear surrounded with luminous circles. These are sometimes quite white, sometimes coloured like the rainbow, and frequently attended with a horizontal bright circle, with still brighter spots near the intersections of this circle, with portions of inverted arches of various curvatures. The horizontal circle has also sometimes bright spots nearly opposite to the sun. These phenomena are frequently observed in lower latitudes, especially in the colder months, and in the light clouds which float in the highest regions of the atmosphere. They are not so intimately understood as the rainbow; but, from their usually appearing in frosty atmospheres, there cannot be a doubt that they are produced by the refracting influence of small prismatic crystals of snow. Sometimes, indeed, the forms of the halos are so extremely complicated as to defy all attempts to account for the formation of their different parts; but if we recollect that flakes of snow assume, in their aggregations, a multiplicity of forms equally capricious, we shall see no reason to think them inadequate to the production of all these appearances.

The decomposition of light, by means of refraction, has further led to an explanation of the origin of the colours of bodies generally. When light falls upon an object, and passes, as it were, into its substance, and is extinguished, or *absorbed*, the object, in reference to colour, is *black;* but if the light be entirely reflected, the object is *white.* The various combinations

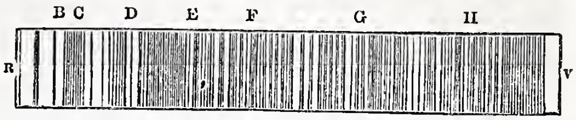
of tints are the consequence of a combination of these two properties—certain rays being absorbed, while those alone whose intermixture produces the observed colour are refracted. This applies also to transparent media: these are colourless, like pure water, when the light passes through unchanged, but are coloured when some rays are transmitted and others absorbed. Thus light passing through glass containing suboxide of copper, is decomposed; the yellow and blue rays are absorbed, and the red rays alone are transmitted. A glass does not possess this property of absorbing certain kinds of lights, because it is coloured, but appears to our vision to be coloured, because it so acts upon white light.

The colours of bodies depend, thus, upon the analysis which they effect of the light incident upon them. It is, however, to be observed of transparent media, that they very generally appear of different colours according as they are seen by transmitted and by reflected light; for it very frequently happens that they transmit other light than that which they reflect. Thus, sea-water, seen by reflection, is of a fine green, but the light which it transmits is pink; and, similarly, a solution of litmus, when seen by transmitted light, is of a rich reddish-purple, but seen by reflected light, is a fine pure blue. In general a portion of the light is reflected from the second surface, tinged like the transmitted portion, which, mixing with that properly reflected at the first surface, modifies its colour. Often, again, the transmitted and reflected lights are complementary, or such as, when mixed together, should produce white light.

The solar beams possess the power of exciting heat as well as light; but the heating power is only developed when the light is absorbed: the temperature of transparent substances through which it passes, and of opaque ones, which reflect it, remains unchanged. Hence the burning glass and concave reflector, are themselves nearly quite cool, though, at the same time, intense heat is developed at the focus. The intense coldness of the higher strata of the air arises, in like manner, from the sun's rays passing on unabsorbed through the atmosphere; and the lower strata would also be very cold, did they not receive heat by contact with the earth.

The distribution of the rays of heat in the prismatic spectrum has been examined with much interest. Sir W. Herschel first directed attention to the subject from the circumstance, that in viewing the sun through telescopes fitted with differently coloured glasses, he sometimes felt a strong sensation of heat when he had little light, and with other colours he had much light with little heat. This observation led to the examination on the heating power of the prismatic colours. Experiment soon proved that these differed very materially in that respect, but it was long before the experimenters could agree as to the point of maximum heat. All admitted that it was nearly associated with the red rays, and that the minimum was to be found with the violet rays; but the precise point was doubtful till Dr Seebeck explained the contradictory statements by showing that the point of greatest heat varies with the kind of prism which is employed in forming the spectrum. With a prism of crown-glass the greatest heat is in the red; with a prism of flint glass, it falls below the red; and with a prism externally glass, and containing water, the hottest part of the spectrum is in the yellow. These experiments have been confirmed by Melloni, who has succeeded with a prism of rock-salt in separating the light and heat of the spectrum almost entirely,—the rays of heat falling below the red, the least refrangible of the coloured rays. This inequality, in refrangibility, existing between the rays of heat and of light, appears to be decisive of the fact, that they are peculiar rays—they can be separated, and must therefore be distinct.

There is another remarkable circumstance connected with the spectrum, which may be briefly stated before leaving the subject. We have hitherto spoken of the band of colours as it appears to common observation—an uninterrupted line of light, red at the one end and violet at the other, and shading away through every intermediate tint from one to the other. In reality, however, this is not the case; it is broken by certain dark lines across it. Some of these abrupt changes are absolutely black, and they are distributed irregularly to the amount of 600 throughout its whole length. But they are constant in the same part of the spectrum, and preserve invariably the same order and relations to each other—the same proportional breadth and degree of obscurity, provided solar light be used. These are called *Fraunhoffer's lines*, from the extreme accuracy with which that philosopher examined and described their positions. To distinguish some fixed points among them, he chose seven of the principal lines marked B, C, D, E, F, G, H, as presenting the double advantage of being easily recognised, and of dividing the spectrum into convenient portions. The following figure conveys an imperfect notion of their distribution:—




Thus B lies in the red band near its extremity; C, is further advanced in the red; D, is a strong double line, in the orange space, very readily distinguished; E, in the green; F, in the blue; G, in the indigo; and H, in the violet spaces. There are besides three very remarkable lines in the green band between E and F.

On examining other lights than that of the sun by the prism, a very remarkable difference is observed, so far as these lines are concerned. The light of the moon, and of the planets—the reflected light of the sun—give the same lines as the direct solar rays; but the black lines in the light of Sirius are altogether different, and the other stars of the first magnitude appear to give rays very different from those both of Sirius and the sun. The electric spark gives very bright lines instead of black. Lamp-light gives also very bright lines; the flames of hydrogen and alcohol give nearly the same lines as those of oil-light.

The only purely homogeneous light, of which we have an example, is that evolved during the combustion of alcohol in which common salt has been dissolved, as in Brewster's *monochromatic lamp.*

The lines being thus invariably the same for light from the same body, and different for different luminaries, we are led to conclude, that they are essentially a property of light. But it must be observed, that the phenomenon seems to be, in some measure, connected with the media through which the light is transmitted. Thus, Sir D. Brewster has lately found that the white light of oil-flames requires merely to be sent through a gaseous medium (nitrous acid vapour), to acquire more than a thousand dark lines in its spectrum. He, thence, infers that it is the presence of certain gases in the atmosphere of the sun which occasions the observed deficiencies in the solar spectrum; and ventures to prophesy that it will yet be in the power of science to study the nature of the combustion which lights up the suns throughout the visible creation.

# MECHANICS.

## PART I.—STATICS.

### CHAPTER III.

26. Equilibrium of forces acting at one point, and not in the same plane.—27. Composition of three forces. Parallelopiped of forces.—28. Polygon of forces.—29. Experimental example.

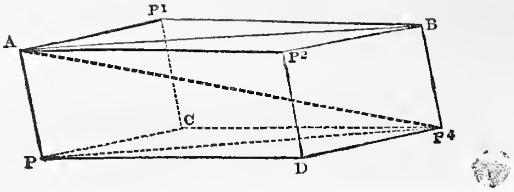
26. In last chapter all systems of equilibrating forces were classified into those exerted on a point, and those acting on many points. We then examined all those cases of the two classes in which the directions of the forces lie in one plane. The other cases, therefore, in which the forces are not in the same plane, remain to be considered.

Of these we shall, as before, first examine the conditions of equilibrium of systems of forces acting at one point.

The directions of two forces at one point, it is easy to see, will always be found to lie in one plane. As, however, there may be applied other forces at that point, which do not lie in this plane, it is evident that there must be more than two forces in systems such as we are considering; in fact, that three forces at the same point is the simplest case at present to be examined.

Let $A\,P_1$, $A\,P_2$, $A\,P_3$, represent, in magnitude and direction, three forces which do not lie in the same plane, and acting at the same point, A. Then, as any two of them will lie in one

plane, the resultant of these two may be found by the method of the parallelogram already explained. For example, $A P_1$ and




$A P_2$ are in one plane, and their resultant is found by drawing $P_1 B$ parallel to $A P_2$, and $P_2 B$ parallel to $A P_1$. The diagonal, $A B$, of the parallelogram thus formed upon the lines $A P_1$ and $A P_2$, will represent the resultant of the forces $A P_1$ and $A P_2$. Now this force, $A B$, may properly be used, instead of $A P_1$ and $A P_2$, in finding the general effect of the three original forces; so that our next step is to find the resultant of $A B$, and the remaining force $A P_3$. Here, again, we have two forces, $A B$ and $A P_3$, acting at one point, A, and, therefore, also lying, like the first two, in one plane; so that the method of the parallelogram may be applied to them also. Draw, therefore, $B P_4$ parallel to $A P_3$, and $P_3 P_4$ parallel to $A B$, forming, thereby, the parallelogram $A B P_4 P_3$. The diagonal drawn from A, as before, is the resultant of $A B$ and $A P_3$; but as $A B$, again, is the resultant of $A P_1$ and $A P_2$, these two forces may be substituted for $A B$, and the line $A P_4$ will, in fact, represent, in magnitude and direction, the resultant of the three original forces, $A P_1$, $A P_2$, $A P_3$.

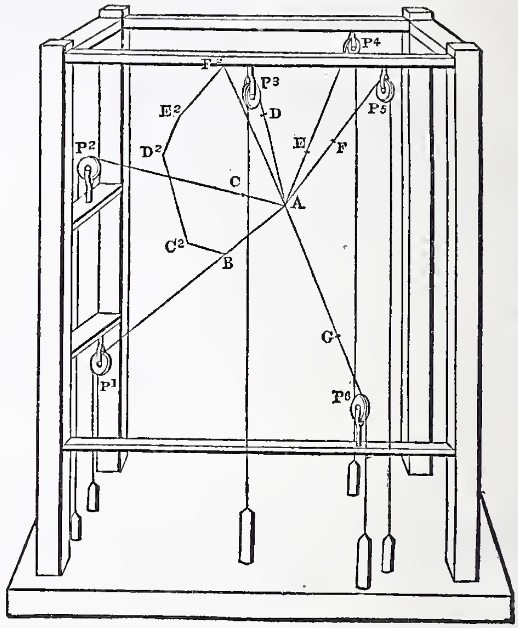
27. Further, if the parallelograms $A P_1 C P_3$, and $B P_2 D P_4$ be completed, which may easily be done, as two sides of each of them are already there; and if $C P_4$ and $P_3 D$ be drawn joining the opposite corners, the figure thus formed will be that of a parallelopiped—by which is meant a solid body having six sides, the opposite sides being parallel to each other, and being themselves parallelograms, which is easily observed in the figure. And the three forces $A P_1$, $A P_2$, $A P_3$ are represented by the three edges which meet at one corner, A, while their resultant $A P_4$ is expressed by the diagonal of the parallelopiped drawn from the same corner. In fact, a parallelopiped may be constructed with any three forces meeting at the same point, and not in *one* plane, and the diagonal, in the same manner, will always represent their resultant. By what has been said, the following proposition is established: *If three forces be represented in magnitude and direction by three adjacent edges of a parallelopiped, their resultant will be represented in magnitude and direction by the adjacent diagonal.* This principle may shortly be termed that of the *parallelopiped of forces.*

It appears from what has been said, that three forces, not in the same plane, can never equilibrate about a point, since a parallelopiped may always be constructed upon them, the diagonal of which will represent their joint effect in magnitude and direction. But if another force be added to the number, equal and opposite to the resultant, $A P_4$, of the three $A P_1$, $A P_2$, $A P_3$, it will balance these three, and establish equilibrium. Thus it appears that there must be at least four in a system of forces not in the same plane, and which equilibrates about one point of application.

28. It has been already stated that the sides of a triangle, taken in order, represent, in magnitude and direction, three forces in equilibrium acting at one of its angles. (12). In the present case, then, the sides of the triangle $A B P_4$, namely, $A B$, $B P_4$, $P_4 A$, represent in order the equilibrating forces $A B$, $A P_3$, (for $A P_3$ is equal and parallel to $B P_4$,) and a third force equal and opposite to $A P_4$, already mentioned in the preceding paragraph. But of these three, $A B$ was found to be the resultant of $A P_1$ and $A P_2$; or, if for $A P_1$ be substituted $P_2 B$, which is equal and parallel to it, $A B$ is equivalent to $A P_2$ and $P_2 B$; so that if these two forces be put for $A B$ in the triangle $A B P_4$, they give the four forces $A P_2$, $P_2 B$, $B P_4$, and $P_4 A$, which, though not in the same plane, are in equilibrium about the point A, and they form the four-sided figure $A P_2 B P_4$. This figure, therefore, is the *polygon* of the four equilibrating forces.

The polygon of forces not in the same plane, may be formed in a similar manner to the polygon of forces which are in the same plane. For instance, from the extremity of the force $A P_2$, we draw $P_2 B$ equal and parallel to $A P_1$, and, again, $B P_4$ equal and parallel to $A P_3$; and, lastly, if we join $P_4 A$, this gives the equilibrating force of the original three. Or we may begin with $A P_1$, and from the point $P_1$ draw $P_1 B$ equal and parallel to $A P_2$; $B P_4$ equal and parallel to $A P_3$, and draw $P_4 A$, as before, forming another polygon; and so on. All these varieties of polygons, however, agree in giving the same equilibrating force, $P_4 A$. By this process, then, as before, we find the conditions necessary to the equilibrium of a system of forces acting on a point, and not in the same plane. If a complete polygon be formed, however irregular in form, the forces must be in equilibrium; and, on the contrary, if the line drawn equal and parallel to the last force of the system do not complete the polygon, there would require to be drawn another line joining the first and last forces to render it complete; and this line would represent that there had been before so much unbalanced force in the system.

29. To exemplify, by experiment, the action of three or more forces in equilibrium at one point, let there be a square frame, on which pulleys may be fixed, at various parts, to direct the




action of the forces employed. Let A be the point acted on, at which the cords $A P_1$, $A P_2$, $A P_3$, $A P_4$, $A P_5$, $A P_6$, all meet, weights being suspended over the pulleys at the ends of these cords. When the system has come to rest, the law of the polygon of forces will be found to be observed. Let us take, for example, $A B$, a distance along $A P_1$, containing as many inches as there are ounces in the weight suspended over the pulley $P_1$. In like manner, measure $A C$, being also as many inches long as there are ounces in the weight over the pulley $P_2$. So also, measure off $A D$, $A E$, $A F$, and $A G$, having all as many inches in their lengths as there are ounces in the weights suspended by them. Now, let the cords be fixed in their positions as they hang over the pulleys, so as to keep the point A also fixed. For the purpose of forming a polygon of the forces, mark off along a piece of wire, one after another in order, the successive distances $A B$, $A C$, $A D$, $A E$, $A F$, and $A G$. Let the first division of the wire be applied to the cord $A B$; then, at B, bend the next division into the position $B C_2$, parallel to the cord $A C$; and as $B C_2$ is also equal to $A C$, it will represent it properly in magnitude and parallel direction. In the same way, bend the remaining divisions of the wire successively into the positions $C_2 D_2 E_2 F_2 A$, all of them being thus equal and parallel to the forces represented by the other corresponding cords. It will be found that the extremity of the last division of the wire, $F_2 A$, meets the end of the first division $A B$, at A; and it will form the polygon $A B C_2 D_2 E_2 F_2$.

There still remains for consideration, the conditions of equilibrium of systems of forces not in the same plane, and which act on different points. But we shall defer our remarks on this part of the subject till we are further advanced, as it is more intricate than any of the preceding cases, and, at present, any attempt at explanation would confuse or convey inadequate ideas.

## CHEMISTRY OF INORGANIC NATURE.

### CHAPTER III.

#### ANALYSIS OF AIR AND WATER.

In our last paper, under this general head, it was stated that the atmosphere consists essentially of two distinct gaseous bodies, oxygen and azote; but as this goes distinctly in the face of the old and still popular doctrine of the "four elements," it may be necessary to examine whether the statement is founded upon sufficient evidence.

Most persons are aware that a lighted taper is extinguished, after burning a short time in a quantity of air, included in a glass-jar, inverted over water to prevent communication with the external atmosphere. During this very simple experiment, it is further observed, by the rise of the water in the jar, that the air gradually diminishes. There is, however, a more accurate form of the experiment, which is liable to less objection. Suppose that, instead of inverting the jar over water, we use a large receiver, whose edges are ground so as to render it air-tight, like the receiver of an air-pump when standing on a brass-plate; and suppose that, instead of the lighted taper, we place under the receiver, upon a stand, a small piece of phosphorus which we can ignite by means of a burning-glass. During the burning of the phosphorus, it will be observed that a new species of matter is formed and falls upon the plate like snow. When the flame is extinguished, and the apparatus cooled down to its original temperature, if we place the mouth of the receiver under water, and remove the plate, a quantity of water will rush in and fill *one-fifth* of the capacity of the receiver; in other words, one-fifth of the quantity of air originally confined in the receiver disappears during the experiment.

In reference to this result, one question immediately occurs—what has become of this air? An ordinary observer might satisfy himself with the answer—it is *consumed*, it is *burned:* but these explanations have no meaning—the air cannot have been annihilated; it must exist somewhere. But, before we attempt to assign the answer, we may observe that there are many other processes that would equally diminish the quantity of air under the receiver. Thus, if a liquid, prepared by boiling some water on a little lime and sulphur, be placed within it, and all communication with the atmosphere be cut off, the result after some time is precisely the same—one-fifth of the air disappears. The experiment is easily made by agitating some of the liquid in a large bottle which is well corked—if the cork be removed under water, a quantity of water will rush in equal in bulk to the air absorbed. If, instead of this solution, we employ a solution of lead in quicksilver, the result is the same—one-fifth of the air disappears. Even quicksilver itself may be used in the experiment. In this case, however, the metallic liquid must be kept boiling for a great length of time in a flask filled with air. During the operation, a very remarkable change is observed—the quicksilver loses its fluidity and metallic splendour, and passes into a red scaly substance resembling red lead in appearance.

The residual air which we obtain in these experiments has very different properties from those of common atmospheric air. Its specific gravity is less, and it neither supports combustion nor animal life. Phosphorus, in a state of intense inflammation, is instantly extinguished by it; and a small animal placed in a jar of it almost instantly expires. It is, moreover, colourless and inodorous. *All* these properties belong only to that gas which we have called *azote*, a name which it has obtained from its noxious influence upon life, (from *ἀ no*, and *ζωὴ life*). It is, however, very commonly called *nitrogen* on account of its entering into the composition of nitre—(*νιτρον, nitre;* and *γεννάω*, to *produce*). It was first distinguished by Professor Rutherford, of Edinburgh, in 1772.

In the experiments described, we invariably find that one-fifth of the air disappears; and the natural inference is, that it unites in some way with the substance submitted to its action, and lies concealed in the new species of matter formed. This inference is further justified by the fact, that whenever any one of the experiments is made with sufficient accuracy, we find that the weight of the new matter is equal to the weight of the material employed and of the deficient air. Thus, in the first experiment, the weight of the white substance formed is found to be exactly equivalent to that of the phosphorus burned, and of the air which disappeared; and, in like manner, the red scaly substance formed during the boiling of the mercury surpasses the weight of the mercury employed by all the quantity of air absorbed. This air may, moreover, be always recovered. The process is, indeed, sometimes difficult, but never impracticable. Taking the simplest case before us—if the red matter, obtained in the last experiment, be placed in a small retort, the beak of which is dipped under the edge of a glass jar filled with water, and standing upon the shelf of a pneumatic trough; and, if we then increase the heat to ignition, it will restore every particle of the air absorbed, and the metal will reappear in its metallic form. The gas which rises into the jar will appear to differ in no respect from common air—it is elastic, transparent, colourless, and inodorous. It is, however, very different in other respects from that portion of air which the mercury refused to absorb; that portion instantly extinguishes flame; but if a newly extinguished taper, with the wick still ignited, be immersed in the portion of air recovered from the mercury, the taper will re-kindle and burn in it with great splendour. Phosphorus burns in it with a brilliancy which is intolerable to the eye, and forms the same snow-white compound which is produced by its less vivid combustion in common air. Ignited charcoal, when introduced into it, likewise burns with great splendour, producing brilliant scintillations; and if we attach a small morsel of glowing tinder to the end of a bunch of twisted iron wire, and place it into a jar of the gas, the metal will speedily begin to burn, and present a most striking and beautiful display of fire. It, moreover, supports animal life; and animals confined in it live much longer than in an equal bulk of common air.

From these experiments, then, it appears that we are able to separate atmospheric air into two other airs, diametrically opposite, at least in one property, and both of them perfectly different from the original. One of the airs is so different from the atmosphere that it extinguishes flame, and the other is so different that it rekindles the flame, which the original air could not have done. From these facts it follows, that if the two be mixed together, an air should result, having an intermediate power of supporting flame and animal life, and this is precisely the case; the two airs are obtained from atmospheric air, it being composed of them. And every one knows that, in the atmosphere, a candle burns precisely in the moderate way which might be inferred from the contrasted nature of the two constituent gases.

The sum, then, of all the preceding details is as follows:—It has been shown that by heating mercury in atmospheric air, and some other processes, a portion of the air is absorbed, and another is not. The unabsorbed portion extinguishes flame and life, and is thence called *azote*. The absorbed portion, when recovered, supports flame and life, and has thence been called *vital air*. And for reasons which will be hereafter explained, it is called *oxygen gas*. In consequence, it appears that atmospheric air is composed of these two gases—oxygen and azote—in the proportion of $\frac{1}{5}$th of the oxygen to $\frac{4}{5}$ths of azote, both estimated by bulk under the same pressure.

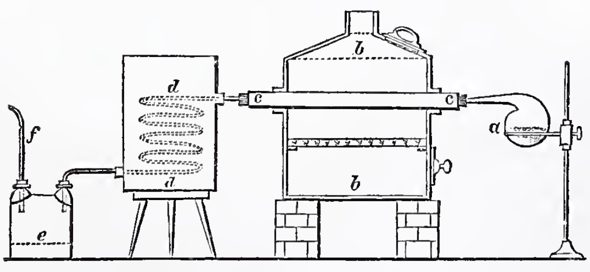
In this view of the constitution of the atmosphere, we have ample scope for admiration of the design and precision which are manifest. To understand this, we have only to look at the consequences which would follow were our atmosphere to be instantly converted into either of the two gases. In pure oxygen the world would run through its stages to destruction in a rapid cycle. Animals would live, as it were, too rapidly; all the vital functions would be increased to a hundred-fold intensity, and fever and death would terminate their mortal career in a few hours. Combustion, once excited, would proceed with ungovernable violence—every case of it would be a case of conflagration—and no vestige even of vegetable life could escape in the universal devastation. Again, should the oxygen of the air be annihilated, animal life would be immediately extinguished, and vegetation would cease. Nay, further, supposing the gases to remain in proportion as they are, but that an increase takes place in their attraction for each other, this would cause them to enter into chemical combination; and the resulting compound, together with the aqueous vapours in the atmosphere, would fall upon us in showers of *aqua fortis* (nitric acid). Even although the compound should retain its gaseous state, and had none of the poisonous properties of this corrosive acid, the use of the at-

mosphere to animal life would be in part, if not wholly, destroyed; for the divellent force would require to be proportionately great, and the tranquil process of breathing would be exchanged for one of violence and strong exertion. We would, moreover, have the noxious products of respiration accumulated round the spots frequented by animals, instead of being rapidly diffused and replaced by fresh vital air. But all these cases are, fortunately, obviated—our atmosphere is a wholesome mixture of the two elements, each neutralizing the other's baneful influence; and, accordingly, life runs quietly through its allotted space, and the current of nature flows within prescribed limits, moderately and manageably.

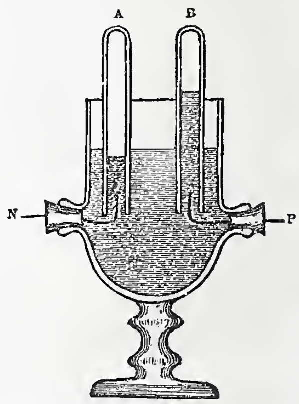
Water, we have said, is an ingredient always found in the atmosphere; we may, therefore, next inquire into its pretensions to the rank of an element.

Fire and water have, from time immemorial, been reckoned the opponents of each other. If, however, we throw a piece of the metal *potassium* (metallic base of potash) upon the surface of water, it will float upon it, and flame will instantly burst forth from the point of contact, and continue until the metal has disappeared. Sodium (the metallic base of soda) will similarly burn, if the water upon which it is thrown be a little warm. There is, however, a much more instructive form of this experiment. Suppose that we invert a tall glass jar, full of water, upon the shelf of a pneumatic trough, and wrapping up a bit of potassium or sodium in a bit of paper, dexterously slip it under the edge of the jar; the metal is thus, momentarily, protected from the water, which, however, soon reaches it, and it then bursts forth into flame. But, during the combustion, it may be observed that a large quantity of gas rises to the top of the jar, and displaces the water. Upon examination this gas is found to possess very remarkable properties. It is exceedingly light, being scarcely more than $\frac{1}{15}$th of the same bulk of common air. It is very inflammable: a small stream of it issuing through a small orifice may be ignited, and will emit intense heat, with very little light; yet a lighted taper immersed into a jar of it will be instantly extinguished. It is, therefore, of a nature quite different from the two gases which have been already described. It does not resemble oxygen, which increases the intensity of the flame of a burning taper immersed in it; and it is not like azote; for this can neither be inflamed, nor will it support combustion.

This gas may be procured by less expensive methods than that described. The one which bears most directly upon our subject is the following:—In illustrating the properties of oxygen, it was stated that iron might be burned in an atmosphere of that gas; and if the experiment be actually performed, it will be observed that the iron melts down into black brittle globules, no longer metallic, although still possessing some metallic lustre, and attractable by the magnet—a property of iron. These globules are a combination of iron and oxygen, and are identical with the black brittle scales struck from a white-hot iron bar by the hammer. They are, therefore, an *oxide of iron;* and we shall hereafter see that the oxygen and the iron may again be separated and recovered. With these facts before us, let an apparatus like the following be constructed:—Here *c c* is a tube




of iron, porcelain, or the like, filled with iron-wire or turnings; it passes through a furnace *b b*, where it is brought to a white, or full-red heat, by a charcoal fire. Into the one end of it the beak of a glass retort, *a*, containing some water, is fitted; and into the other end is fitted the end of a spiral tube, which is surrounded with water, in a vessel *d d*, to keep it cool. The other end of this spiral tube communicates with a double-necked vessel, called a Wolfe's-bottle, into the other neck of which a second tube, *f*, is fitted. These tubes should not descend to the bottom. The end rising above the bottle may be conveyed to a pneumatic apparatus, or have a flaccid bladder, from which the air has previously been well squeezed out, tied upon it. When this arrangement is complete—if the water in the retort be made to boil briskly—the steam will pass through the tube *c c*, and be thus brought into contact with the red-hot wire in it. Some portion of it will pass through unchanged, and be condensed in the spiral tube, and the water so formed will be received into the Wolfe's bottle, but by far the larger product which passes through the apparatus, will be an incondensible gas; this will find its way through the tube *f*, and may be collected in any convenient way. This gas, on examination, proves to be exactly the same as that obtained by burning potassium on water. But there is another fact to be observed. When the apparatus has cooled down, and the iron wire contained in the tube *c c* is examined, it is found to have lost its flexibility, and is, in whole or in part, (according to the duration of the experiment,) converted into a substance, which is in every respect identical with the black oxide of iron already described. Now, the question occurs:—whence was the oxygen derived which thus united with the iron? The answer is obvious. The only substances concerned in the experiment are iron and water; it is, therefore, manifest that the water must have supplied the oxygen,—and if so, water must contain this gas as one of its component parts. We are thus led to the conclusion, that water is not itself an element, but is resolvable into oxygen and an inflammable air, which we have not yet named, and must therefore be composed of these gases as elements.



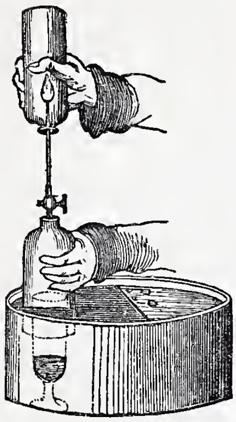

The result of this experiment may be verified directly by means of the galvanic battery, and an apparatus like that depicted on the margin. This is a glass cup, with apertures on either side, for the reception of two corks. Through these corks platinum wires are passed, communicating with the galvanic battery,—P being attached to the positive, and N to the negative pole. A B are two glass tubes, both filled with water, and inverted in the cup, which also contains water, and thus serves the purpose of a pneumatic trough. When the connexions are made with the battery, gas begins to rise in the tubes, and displace the water in them. After the action has continued some time, it will be observed that there is exactly double the quantity of gas in the one tube that there is in the other; and further, that these gases are entirely different,—that in the tube A being in every respect identical with the light inflammable air described above; while that in the tube B is pure oxygen. Moreover, were we to weigh the gases in the tubes, we should find that that in A weighs exactly an eighth part as much as the oxygen in B—their specific gravities are, therefore, as 1 to 16.

This experiment, then, leaves no doubt that water is composed of the two gases described: we here obtain them unmixed, and can weigh and measure them, and examine their properties. It is, indeed, somewhat inconvenient, and the apparatus figured cannot be always procured; it may, however, be much simplified for parlour experiments. Thus, instead of the perforated glass cup and tubes, we may use a single tube of $\frac{3}{8}$th inch diameter, bent into the form of a V, with a small hole drilled at its outer angle. When this tube is filled with water, a cork, having a piece of iron wire passed through it, is inserted into each end. The wires are thus made to approach each other to within half an inch of meeting at the angle. When the connexion is made with the battery, the gases will ascend in the legs of the tube, and will displace the water through the little aperture drilled at the bottom.

These facts, then, prove very distinctly that we can obtain two gases from water, and we thence infer that these are its component elements. This inference may, however, be subjected to a still more severe test; for if water can be decomposed into two gases, we are strictly justified in expecting that it will be formed by their reunion. In proceeding to this synthetical

examination of the question, we find that the two gases when mixed, remain unaltered; their particles seem to be at such a distance from one another while in the elastic state, that they are not within the limits of each other's attraction. But if the gaseous mixture be violently compressed in a strong glass tube, a loud report, accompanied by a vivid flash of light, informs us that some change has taken place; and, accordingly, we now find the gas replaced by steam, which speedily condenses, and becomes liquid water.

This experiment is, however, dangerous; and, owing to the smallness of the quantity of water formed, is by no means satisfactory. But the inflammable air may be burned, as we have already stated, in a small stream, in a vessel containing oxygen; and then the gases combine quietly, and the sides of the vessel are soon covered with trickling streams of liquid, which is limpid and pure water. This experiment is easily performed in the manner depicted on the margin. The essential apparatus is a long capillary tube—it may be the stem of a tobacco-pipe—fitted into one end of a stop-cock; the other end of the stop-cock being fitted into the mouth of a glass-receiver—a wide bottle from which the bottom has been cut answers the purpose perfectly. This receiver is passed over a tall glass, into which some pieces of zinc or iron, with a little sulphuric acid (oil of vitriol) and water, have been put. From these materials the inflammable gas is given off in large quantity.



The glass containing the gas-generating ingredients is placed in a pneumatic-trough, but must rise slightly above the surface of the water. The stop-cock being then opened, and the receiver depressed in the water, gas will flow through the small pipe, and, *after two or three minutes*, may be ignited. Over the flame may then be inverted a dry bottle, and very speedily, dew will begin to be deposited on its interior surface. This dew is water formed by the combination of the inflammable gas with the oxygen of the atmosphere; and, if the process be long enough continued, it will begin to drop from the mouth of the bottle, and may be collected.

From these experiments, then, we can have no difficulty in admitting that water is a compound of oxygen and inflammable air. It may, indeed, appear surprising that from a large volume of the gases only a few drops of the liquid is obtained; but when we reflect on the degree of condensation which takes place, the wonder ceases. An appeal to the weigh-balance informs us, that one cubic foot of water weighs as much as 800 cubic feet of oxygen; it will, therefore, weigh no less than sixteen times 800 cubic feet (12,800 cubic feet) of the inflammable gas; and bearing in mind, that for every measure of the heavier gas which is condensed, there are two of the lighter; we find that no less than 1600 measures of gas are necessary to form one measure of water. The condensation of the oxygen is thus upwards of five hundred times, and that of the inflammable air, a thousand times.

The discovery of the composition of water is usually attributed to Mr Cavendish; but it does not appear that the merit was undivided. He was the first, however, to point out distinctly the nature and properties of the inflammable gas, which, we have seen, is one of its constituents (Philos. Trans. for 1766). He called it, as we have here done, *inflammable air*, on account of its combustibility. By others of the old chemists it was termed *phlogiston*, from the supposition that it was the matter of heat. But these names are now laid aside; and, from the gas being a remarkable element in the formation of water, it has obtained the more appropriate name of *hydrogen*, signifying *water-forming*—(from two Greek words, ὕδωρ, *water*, and γεννάω, to *generate*).

Hydrogen does not support animal life, but it does not seem to be positively injurious; for when mixed with a sufficient quantity of oxygen, it may be respired without inconvenience. The inference is, that it merely kills by excluding oxygen. It could not, however, serve at all as an atmospheric gas; were it substituted for the nitrogen of the air, the first spark of fire kindled on the earth would explode the whole aerial ocean, and convert it into steam. The reason assigned for its destroying life, is also the reason why it extinguishes a lighted taper when immersed into an inverted jar of it. The gas burns, but it does not support combustion. Oxygen, again, supports combustion, but does not burn; and hydrogen, like all other combustibles, requires the aid of a supporter of combustion: that, indeed, which we call combustion, (in ordinary cases,) is simply the uniting together of the combustible and the supporter of combustion. This accounts for the violence of the combustion, which takes place when the two gases are mixed in the proper proportion; that is, in the proportion in which they are found to constitute water; for, in all cases, the result of the combustion of hydrogen in oxygen, is water. By the combustion of these gases we also obtain the most violent heat known. The oxy-hydrogen blow-pipe is an example of this. As the name implies, the gas employed is a mixture of the two of which we have been speaking, and the flame produced, although it yields very little light, is capable of melting, and even burning, the most refractory substances.

During these observations, then, we have arrived at some important facts. We have seen that air and water are very improperly called elements,—that they contain between them one common element, (oxygen,) associated with two distinct elements—azote and hydrogen. These substances hold the most prominent places in creation. We have, moreover, learned that the mild and wholesome air, which is indispensable to organic life, as at present manifested, contains the elements of destruction, and that water, the most incombustible of all bodies, is composed of the very *elements* of fire.

# MATHEMATICS.

## CHAPTER VIII.

### ARITHMETIC OF DECIMAL FRACTIONS.

The rules already established for the addition, subtraction, multiplication, and division of common fractions, apply equally to decimal fractions; but our mode of counting decimals renders the application of these rules more simple. To illustrate this, we shall take the different cases in their order:—

I. Addition.—Suppose it required to find the simple sum of

$$3{\cdot}4051 + 6{\cdot}503 + {\cdot}01 + 7{\cdot}1 + {\cdot}0065.$$

By reducing these quantities to a common denominator, as directed in the general rule for the addition of fractions, (p. 230, art. 1.), and exemplified for decimal fractions in our last chapter, (p. 302, art. 9, and IV.), we get

$$3{\cdot}4051 + 6{\cdot}5030 + {\cdot}0100 + 7{\cdot}1000 + {\cdot}0065.$$

These are fractions whose common denominator is 10000: their sum by the general rule is therefore

$$\frac{34051 + 65030 + 100 + 71000 + 65}{10000} = \frac{170246}{10000}$$

And $\frac{170246}{10000}$ represented according to the new notation is $17{\cdot}0246$

In this way we may find the sum of any series of decimal fractions; but a little reflection serves to convince us that the mode of proceeding may be abridged. Thus, bearing in mind that our fractions decrease in value from the decimal point towards the right, exactly as whole numbers do (p. 302, art. 7.), it is very obvious that such an operation, as that shown above, might be resolved into the same form as if the quantities were whole numbers. The only condition necessary is, that all the figures of the same *local value* shall be found in the same vertical column; and this condition is readily fulfilled by writing down the decimals in such a way that the decimal points may be exactly under one another. This disposition is shown on the margin in (I); and it will be observed from a comparison of (I)

| (I.) | | (II.) |
|---|---|---|
| 3·4051 | = | 3·4051 |
| 6·503 | = | 6·5030 |
| ·01 | = | ·0100 |
| 7·1 | = | 7·1000 |
| ·0065 | = | ·0065 |
| 17·0246 | = | 17·0246 |

and (II) that this keeping of the decimal points, under one another, is practically equivalent to reducing the fractions to a common denominator, as the ciphers annexed to the quantities in (II), obviously do not affect the result of the addition. We may, therefore, state the following as the practical rule for the addition of decimal fractions:—

*Write the quantities under one another so that the decimal points may be in the same vertical line—then add as in common addition, and place the decimal point in the same under the other decimal points.*

The following cases will serve as exercises in the application of this rule—they ought, however, in the first place, to be performed by the general rule for the addition of fractions—

$$45{\cdot}07 + 50{\cdot}758 + 123{\cdot}0057 + 74{\cdot}702 + 24{\cdot}8 = 318{\cdot}3357$$
$$\cdot678953 + \cdot79643 + \cdot0546 + \cdot789 + \cdot9 + \cdot00071 = 3{\cdot}219693$$
$$\cdot975642 + \cdot745257 + \cdot000598 + \cdot8007 + \cdot64053 + 1 = 4{\cdot}162727$$

II. Subtraction.—Suppose it required to find

$$6{\cdot}739 - 5{\cdot}96789 = ?$$

These fractions reduced to the common denominator, 100000 are

$$6{\cdot}73900 - 5{\cdot}96789 = \frac{673900 - 596789}{100000} = \frac{77111}{100000} = \cdot77111$$

But here we have the same abridgment to make as before: for, by writing the quantities with the decimal points under each other, we reduce them virtually to the same denominator: and we may, therefore, proceed with the operation as if they were whole numbers—as shown in (I) which is equivalent to (II); but in which we have saved ourselves the *trouble of writing* two ciphers on the right of 6·739 : these ciphers must, however, be supposed to be so placed when we proceed to make the subtraction. The following is the practical rule:—

| (I) | (II) |
|---|---|
| 6·739 | = 6·73900 |
| 5·96789 | = 5·96789 |
| 0·77111 | = 0·77111 |

*Write the less fraction under the greater, so that the decimal points may fall under each other; then subtract the lower from the upper line, and whenever there is a figure in one line and not in the other, proceed as if there were a cipher in the vacant place. Place the decimal point of the difference under the other decimal places.*

The following instances will serve for exercise in the rule:—

$$\cdot547893 - \cdot439758 = \cdot108135 \qquad 562 - 93{\cdot}5784 = 468{\cdot}4216$$
$$75{\cdot}0034 - 57{\cdot}875 = 17{\cdot}1284 \qquad 1 - \cdot997543 = 0{\cdot}002457$$
$$3{\cdot}0004 + 70{\cdot}5 + \cdot008 - 27{\cdot}307253 - 2{\cdot}020133 = 44{\cdot}181014$$

III. Multiplication.—It is a very manifest fact, that if two decimal numbers be multiplied together, the product has as many ciphers as are in both together. Thus, $100 \times 1000 = 100000$, and $10000 \times 100 = 1000000$. Now, the denominators of decimal fractions are decimal numbers; and, therefore, it is plain that the denominator of the product which is formed by multiplying any two such fractions together, and which is the product of the denominators, must have as many ciphers as are in the denominators of both fractions—and, since the numerator of the product is the product of the numerators, it is clear that the decimal point must be placed in that product so as to cut off as many decimal places as are in both the multiplier and multiplicand.

$$\text{Thus, } 1{\cdot}2 \times \cdot13 = \tfrac{12}{10} \times \tfrac{13}{100} = \tfrac{156}{1000} = \cdot156$$
$$\text{But, } 1{\cdot}2 \times 1{\cdot}3 = \tfrac{12}{10} \times \tfrac{13}{10} = \tfrac{156}{100} = 1{\cdot}56$$
$$\text{And, } \cdot12 \times \cdot13 = \tfrac{12}{100} \times \tfrac{13}{100} = \tfrac{156}{10000} = \cdot0156$$

Hence we may give the following as the practical rule for the multiplication of decimal fractions.

*Multiply the given fractions as in common multiplication, disregarding the points and all preliminary ciphers; then point off as many decimal places from the right of the result, as there are decimal places in* BOTH *multiplier and multiplicand. If there be not as many figures in the result as there ought to be decimal places, make up the deficiency by* PREFIXING *ciphers:—*

The following results may be proved both by this rule and the general rule for the multiplication of fractions.

$$57{\cdot}056 \times \cdot578 = 32{\cdot}978368 \qquad \cdot56879 \times \cdot05674 = \cdot0322731446$$
$$7{\cdot}6543 \times 5{\cdot}4246 = 41{\cdot}52151578 \qquad \cdot03246 \times \cdot02364 = \cdot0007672544$$
$$0{\cdot}2365 \times 0{\cdot}2435 = 0{\cdot}05758775 \qquad 87649 \times \cdot03687 = 3231{\cdot}61863$$

IV. Division.—The nature of the process for the division of one decimal fraction by another may be shown thus:—

Let it be required to divide ·369 by ·0625.

The dividend ·369 is $\frac{369}{1000}$, and the divisor ·0625 is $\frac{625}{10000}$;

Therefore $\cdot369 \div \cdot0625$ is $\frac{369}{1000} \div \frac{625}{10000} = \frac{369}{1000} \times \frac{10000}{625} = \frac{3690}{625}$,

and $\frac{3690}{625}$ reduced to a decimal is 5·904.

From this operation it appears, that if we make the number of decimal places the same in the divisor and dividend, and reject the decimal points and all preliminary ciphers, the *altered dividend* may be taken as the numerator, and the *altered divisor* as the denominator of a common fraction, which, when reduced to a decimal, (either exactly or approximately), will be the quotient required. To show this more fully, suppose it required to divide 636·058 by 8·6. These fractions reduced to a common denominator, are 636·056 and 8·600, and their quotient is therefore $\frac{636{\cdot}056}{8{\cdot}600} = \frac{636056}{8600}$, which must be reduced to a decimal fraction, by the rule for that operation, (p. 302, art. II.) The process at full length is as follows, leaving out, in the first instance, the ciphers of the divisor.

Here, three ciphers have been annexed to the remainders, in making this division, and two were taken from the divisor; we must therefore make *five* decimal places in the quotient, which then becomes 73·96023, and this is the quotient of 636·058, divided by 8·6. It is, however, only the approximate quotient; for the division is not complete, as is shown by the remainder 22; the approximation may be carried much farther, and if the unit be very large, it may be necessary to extend it; but, however far it may be carried, the same principle applies. We may therefore now write down the practical rule, which is as follows:—

```
86)636058(7396023
   602
   ---
    340
    258
    ---
     825
     774
     ---
      518
      516
      ---
       200
       172
       ---
        280
        258
        ---
         22
```

*To divide one decimal by another, reduce the fractions to a common denominator, then strike out the decimal points, and consider the quantities as whole numbers, and proceed with the division accordingly, when that is possible. When the divisor is not contained in the dividend, annex ciphers to it as required; and when the remainder becomes nothing, or when the division has been carried as far as necessary, count the number of ciphers which have been used, and mark off as many places from the right of the quotient, prefixing ciphers if necessary. If the divisor have ciphers annexed to it, they may be struck off, and counted among the number of those annexed to the remainders in making the division.*

This appears to be the plainest way of stating the rule; but with practice, the student will be able to proceed at once with the division, without formally reducing the qualities to a common denominator. As the rule is reckoned difficult, we subjoin a number of examples as exercises.

$$3{\cdot}1 \div \cdot0025 = 1240 \qquad \cdot4368 \div \cdot0078 = 56$$
$$173{\cdot}43 \div 9 = 19.27 \qquad 780{\cdot}516 \div 24{\cdot}3 = 32{\cdot}12$$
$$192{\cdot}1 \div 7.684 = 25 \qquad 17{\cdot}762 \div 6{\cdot}25 = 2{\cdot}84192$$

$$\frac{\cdot6}{6} = \frac{6}{60} = \cdot1 \qquad \frac{\cdot06}{60} = \frac{6}{6000} = \cdot001 \qquad \frac{\cdot006}{\cdot6} = \cdot01$$
$$\frac{6}{\cdot6} = \frac{60}{6} = 10 \qquad \frac{60}{\cdot06} = \frac{6000}{6} = 100 \qquad \frac{\cdot06}{\cdot006} = 10$$

$$8792 \div 937{\cdot}6567 = 9{\cdot}37657$$
$$7{\cdot}361 \div \cdot855 = 8{\cdot}609356608187369\ldots.$$
$$\frac{\cdot59}{79800} = \cdot000007393483 \qquad \frac{\cdot0007475}{\cdot575} = \cdot0013$$
$$\frac{23}{\cdot000579} = 39723{\cdot}66148532 \qquad \frac{\cdot2}{23{\cdot}2} = \cdot00862069$$

By means of these rules all calculations with decimals may be performed; but there are certain methods of abridgment, and some rules for finding the *exact* products and quotients of interminable decimals, to which it will be necessary to return.

# GEOLOGY.

## CHAPTER X.

### SLATE OR CAMBRIAN SYSTEM.

*Slate Rocks.*—The metamorphic character of gneiss, mica slate, clay slate, and other schists, is not confined exclusively to rocks of the oldest formation. In the central Alps of Switzerland, rocks belonging to the liassic, oolitic, and cretaceous systems, according to Mr Lyell, graduate insensibly into granular limestone, talcose schist and gneiss, micaceous schist, and other varieties of slate. Such alternations, however, can only be regarded as exceptions to a general rule, and as tending to show that the older schists of Scotland, and other primary countries, have been altered, by some cause or other, from soft earthy deposits into their present indurated, and, in many instances, semi-crystalline state; rather than invalidating the fact, that the gneiss and schistose structure, may, in general, be regarded as the distinguishing characteristic of the primary formations. In examining slate rocks, we find no difficulty in believing that originally their condition could not have been essentially different from many shales and sandstones common to the carboniferous series. Indeed, some of the soft slates of the Scottish coasts are scarcely distinguishable from certain shales of newer formation, and seem by no means to have undergone such a total change as would have obliterated every trace of organic remains had such been originally imbedded in them. We find very dark varieties of slate alternating with others of a light colour, precisely as do shales of the various tinges of gray, black, blue, red, and green. On subjecting some of the black soft slates to a red heat, we found the colour to change to a light silky grey, not distinguishable from other varieties belonging to the same rocks from which these were taken. Seeing that the original colour had not been destroyed in the mass by the heat to which it is supposed to have been subjected, where is the agency that could have destroyed every vestige of shell, or other organic remains, had such ever existed in it? The entire absence, therefore, of organic forms in the Scottish slates, seems as strongly to favour the supposition, that their deposition took place, either previous to the existence of animated beings upon the surface of the globe, or while they were very few, and limited in their horizontal range, or of such a perishable nature as to have left no trace of their organization; for we can imagine it possible that soft gelatinous animals may have existed in the primary seas long before the testaceous molluscæ were created; but we cannot affirm that they did, or did not, as the fossilization of such animals could only take place under very particular circumstances, and these may not have been in existence in the earliest epochs of sedimentary deposition. The schists of the Scottish highlands are more extensively developed than is generally supposed. Indeed, they attain a thickness equal, if not greater, than that usually assigned by modern geologists to the entire stratification of the globe. The schistose belt extends from the south-west to the south-east, and the dip lies generally between south and south-east. From the junction of the old red sandstone with the slates at Knockamilly, five miles below Dunoon, on the Argyleshire coast, there is a regular development of schistose beds to the mouth of the Holy Loch, a distance of seven miles. The truncated edges of the schists are passed over at a very high angle to the plane of stratification for above seven miles, and, judging from their development, from the mouth of Loch Long to Arrochar, a distance of twenty miles, the entire thickness probably exceeds fifteen or sixteen miles. If we believe in the sedimentary origin of this enormous accumulation, our conception of the time required for the effect produced, is akin to that vague idea of distance impressed upon our minds by the remoteness of the celestial spheres. The sensation awakened by the past infinity of time, during which the waters of the pristine world were laying "the foundations of the earth," is not lessened by the contemplation of their character. In wandering through the gorgeous recesses of the mountain solitudes of the Scottish lowlands, the geologist is naturally led to inquire whether the inequalities of surface—the precipitous mountain—the deep ravine—and the lowly glen, are the work of sudden and awful convulsion, or the results of the slow operation of natural causes now in existence. At first the former idea rushes upon the mind, and we think we perceive in the rugged features of the scenery around us, the stern monuments of violent irruptions—sudden upheavals and sinkings of the crust of the earth; but a more attentive examination of the rocks themselves defaces the impression, and convinces us that stupendous as the effects are, and rugged and precipitous as the mountains appear, the intervening hollows, together with the beds of the intersecting lakes, or arms of the sea, have been scooped out by the agency of currents, and that the whole irregularity of surface is owing to the operation of causes, probably not more violent than those which now waste the rocks upon the shores of the existent ocean, the effects of which are scarcely perceptible in the course of our ephemeral existence.

In some slate beds, cubical crystals of iron pyrites are very abundant. Whinstone dykes are frequently found traversing slate, and changing it into a compact flinty slate near the point of contact.

In North Wales, the slate system contains, 1st. Snowdon rocks, several thousand yards thick, consisting of fine grained, purple, blue, and green slates, fine and coarse graywacke often alternating, and some of the beds containing a few organic remains. 2d. Bala limestone, consisting of dark limestone and shale, containing shells and corals. 3d. Plynlimmon rocks, several thousand yards thick, and consisting of graywacke and graywacke slate, with some beds of conglomerates. The equivalents of these occur in Cumberland in the following manner, commencing also at the lowest beds:—1st. Lowest slaty group of Skiddaw, consisting almost entirely of dark coloured useless slate, the lowest portions being hornblende and chisatolite slate. These beds rest on a mere trace of gneiss and mica slate reposing on granite. 2d. Middle slaty group of Langdale and Borrowdale, 1000 yards or more in thickness, and consisting of dark flaggy and slaty rocks in the upper division, in the middle of fine green slates, near the bottom of which most of the rocks are mottled, amygdoloidal, and fragmentary. The lowest bed is a red mottled rock, and sometimes appears as a conglomerate. 3d. The slaty limestone of Coniston and Lowwood, about 100 yards thick, and containing both shells and corals. 4th. Upper slate group, 1000 yards or more thick, consisting, 1st. Of a great mass of graywacke. 2d. Of alternating beds of graywacke and graywacke slate.—*Phillips.*

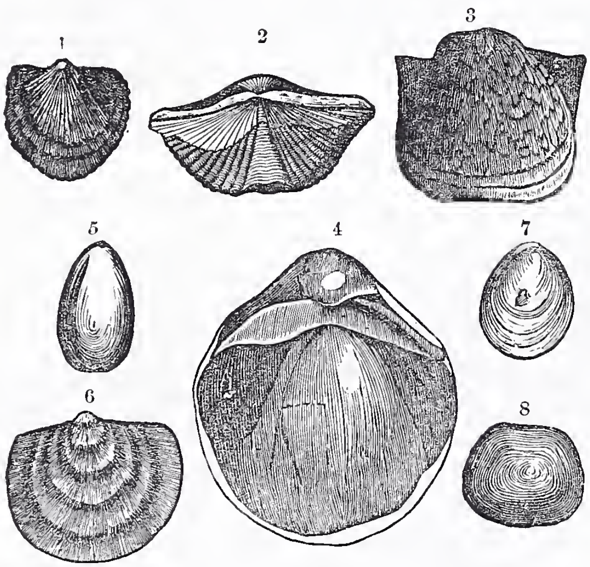
Are we to regard the formation thus described as having been deposited at the same time as the slates of Scotland? No organic remains having been yet discovered in the latter, we are left with no other means of determining, save their stratigraphical position. Both the schistose system of Scotland, and the old red sandstone, seem to be much more extensively developed than in England or Wales; while the silurian, or at least rocks containing silurian fossils, are unknown. The circumstance is certainly very remarkable, and might lead us to suppose that no inconsiderable portion of the Scottish slates belong to the silurian era; but this, probably, can only be determined when fossil remains are discovered; and their discovery is not altogether hopeless, seeing that so very little attention has been paid to the subject in Scotland.

In the slates of Snowdon, Professor Phillips discovered twelve species of shells and corals. With regard to which, he observes, "It may surprise the speculators in cosmogony to hear that the most ancient forms of life known to us should not be plants, but animals, not merely zoophytes, but conchifera, not the lowest grades of their respective classes, but well-developed lamelliferous (1) zoophytes, (2) and brachiopodous (3) molluscæ. No gasteropods, (4) or cephalopods, (5) are, however, as yet mentioned as having been found in these rocks in Britain, and we do not feel sufficiently acquainted with the geological age of the Hartz to introduce any of the fossils of that argillaceous range of mountains. Whether at the time of the formation of these ancient rocks in the sea, plants were growing on the land—whether, indeed, there were dry land we must not even conjecture. That plants were growing in the sea which nourished the shells and zoophytes, is a probable, but not a certain inference, since seaweed does not alone constitute the food of conchifera (6) or zoophytes."

The shells figured by Professor Phillips from Snowden, are two species of corals, and shells of the genera producta, spirifer and terebratula. As these shells present to us the first forms of animal life with which we are acquainted, a knowledge of their structure is necessarily of deep interest.

They belong to the brachiopods, or spiral armed molluscæ, which form the fifth class of Cuvier's arrangement of that division of the animal kingdom. These molluscæ have bivalve shells, and are possessed of a mantle, which, besides performing the office of secreting the substance forming the shells, is subservient to the circulating system. Instead of the branchiæ, or respiratory organs, occupying the usual place, as in the ordinary bivalves, there are usually two long fringed and spiral arms, whilst the branchiæ present themselves on the internal surface of both lobes of the mantle, in oblique parallel lines. Those lobes are traversed by vessels of considerable size, which return the blood from the organs of respiration, and these branchial veins terminate in two systematic hearts. The term brachiopoda is used as significant of the fringed arms, which take the place of the foot or organ of progression in the cockle and other bivalve shellfishes. The following are the genera into which the class is divided :—

| | |
|---|---|
| Terebratula | Recent and fossil. |
| Spirifer | Fossil. |
| Producta | Fossil. |
| Strigocephalus | Fossil. |
| Magas | Fossil. |
| Lingula | Recent and fossil. |
| Thecedia | Recent and fossil. |
| Strophemena | Fossil. |
| Orbicula | Fossil and recent. |
| Crania | Fossil and recent. |




1. Terebratula risca. 2. Spirifer undulatus. 3. Producta scabricula. 4. Stigocephalus. 5. Lingula. 6. Strophemena rugosa. 7. Orbicula reflexa. 8. Cranta personata.

We thus see that from the dawn of creation to the present day, the original type of animal existence has been preserved in some of the genera, although the most ancient species disappeared at a very early stage in the history of animal existence.

We shall only notice the distinctive generic character of the terebratula producta, spirifer, and lingula,—these being of most common occurrence in the fossil state, and forming the earliest modes of marine existing. The terebratula has a delicate and equal-sided and rather triangular-shaped shell, which has one of the valves longer than the other and recurved at the beak, which is perforated by a round hole, or by a fissure more or less wide and variable in form, from which a tendinous ligament proceeds by which the animal fixes itself to rocks and other marine bodies. The recent species exist in both extremely hot and cold climates. The average depth at which they live, is from 10 to 90 fathoms. As terebratulæ are found in limestone immediately overlying coal, if the old species lived at as great a depth as the recent, the formation of coal at the surface, as advocated by some geologists, would seem to be somewhat invalidated, unless we allow a great depression to have taken place between the time the coal was formed, and the existence of the shells, and the deposition of the same.

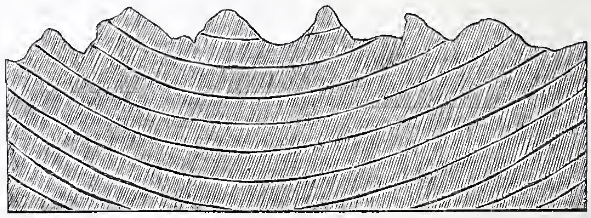
The spirifer is an equilateral unequivalved shell, with a large angular sinus, or canal, along the inside of the beak, with a long, straight, and two spirally coiled tubular appendages nearly filling the shell. The producta is an equal sided, unequivalved bivalve, one of the valves being convex, and the other flat or concave, externally. The beak is not perforated as in the terebratulæ.

The lingula is a flat, thin, ovally oblong, and nearly equal valved bivalve. It is broad at the base, and pointed at the top, from which it is joined to marine bodies by a long fleshy stalk, or pedicle.

The endosiphonites is found in the Cambrian strata; we shall describe it and the class cephalopodata, to which it belongs, in the proper place.

Endosiphonites carinatus.

*Slaty cleavage.*—In examining the slate rocks, we find them affording in many places the most distinct evidence of aqueous deposition in the differeuce of colour and composition of the strata. In other places, the planes of stratification are not so visible, and are apt to be confounded with cleavage, a phenomenon common to many slate beds, and frequently vertical, or nearly so to the stratified planes, as in the following diagram :—



Vertical Section of Slate Rock.

Horizontal strata are sometimes traversed by nearly vertical cleavage; and vertical or highly inclined beds, have sometimes a nearly horizontal cleavage. "In strata," says a writer in the Penny Cyclopedia, "which dip different ways from an axis, the cleavage planes are found to be parallel through the whole mass on both sides of the axis; and even where strata are variously contorted, they are frequently dissected through a great portion of the whole of their mass, by cleavage planes passing in one direction. Hence the conclusion is obvious, that this slaty structure, this monohedral symmetry, (if we may not call it crystallization,) is the fruit of a general cause, acting subsequently to the deposition and disturbance of the strata, which has been capable of pervading and re-arranging the particles so as to polarize and systematize their mutual attractions, but not to fuse them together, or to obliterate the evidence of their original condition. The slaty structure of rocks appears to depend greatly on the nature of the rock, as in some classes the cleavage changes, and even reverses its inclination when the mass is contorted. The old rocks are certainly most subject to the phenomenon referred to, but that it is not altogether dependent on geological time, may be inferred from the fact, that the silurian rocks are found slaty in Pembrokeshire, and not so in Monmouthshire; the mountain limestone shales are slaty near Torbay, but not so in Yorkshire; the lias shales are slaty on the northern slopes of the Alps, and not so in England." "The most general condition which has occurred to our observation is the fact of remarkable displacement of strata, as one or more anticlinal (7) or synclinal (8) axes, and it is of consequence to this inference to remark, that very often, nearly or even exactly, the horizontal edge of the inclined cleavage planes coincides with the axis of movement; and, therefore, with the strike of the stratification. Pressure, in some particular application, appears to be indicated by all the phenomena, as the grand agent in the production of slaty cleavage. Only one tolerably successful effort has been made, experimentally, to produce this structure by art. Mr. R. W. Fox has caused electric currents to traverse

a mass of moist clays, and observed in consequence, the formation of numerous fissures, more or less similar to slaty cleavage, in planes parallel to the bounding surface of the mass, and at right angles to the electric currents. The exact application of this experiment is not understood. Perhaps, however, conjoined with the admission, that the great movements of strata, by which slaty cleavage was determined, depended on the disturbed equilibrium of internal local weight, or rather must have developed electric currents;—this solitary experiment may be the commencement of a right mode of more extensive inquiry, embracing the many circumstances of chemical nature,—stratified arrangement, disturbed position, and proximity of aqueous rocks—which must all be included in a good theory of slaty cleavage." Indeed, there can be little doubt, that in all the phenomena which these rocks present, thermo-electrical action has performed a very important office, both in the re-arrangement of the molecules of matter, by which their cleavage has been determined, and their present structure produced, and we have no less an authority than Professor Sedgwick, for concluding, that they cannot be referred to retreat of parts, or contraction of dimensions, but to crystalline or polar forces, acting simultaneously in given directions on large masses, having a homogeneous (9) structure.

☞ (1) Lamelliferous, consisting of laminæ, or thin layers. (2) Zoophyta, coralline animals. (3) Brachiopoda, spiral armed molluscæ, or shell-fish. (4) Gasteropoda, snails, and other inhabitants of spiral univalved shells, as the whelk. (5) Cephalopoda, animals which, like the cuttle-fish, have their organs of prehension and progression situated round the head. (6) Conchifera, oysters, mussels, and other inhabitants of similarly constructed bivalves. (7) Anticlinal line, the line *from* which strata dip in opposite directions. (8) Synclinal line, the line *to* which strata dip from opposite directions. (9) Homogeneous, of the same nature, not mechanically compounded of different substances.

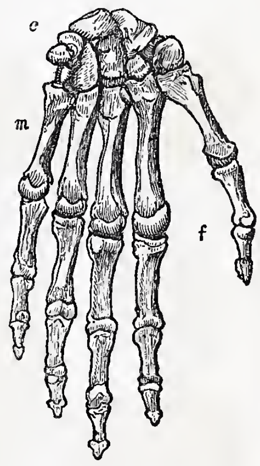
## ANATOMY AND PHYSIOLOGY.

### CHAPTER XI.

THE SKELETON.—*Concluded.*

The upper extremities have a strong general resemblance to the lower—the shoulder corresponding to the pelvis, the arm to the thigh, the fore-arm to the leg, and the hand to the foot; but the differences between them are also very striking. The lower limbs are formed for progression, and for supporting the weight of the rest of the body; the upper are formed for prehension—much less strong, but much more moveable. The shoulder is not fixed immovably to the trunk—the shoulder-blade glides on the back of the ribs, and is joined firmly to the outer end of the collar-bone; and the inner end of this is connected to a socket on the upper corner of the breast-bone, which permits great freedom of motion, but forms a centre round which the shoulder plays, so as to be raised or depressed, or carried forward or backward. The *collar-bone*, or *clavicle*, is slender, curved like a long italic *f*; and as all shocks produced by falls on any part of the upper extremity are transmitted through it—it is one of the bones most frequently broken. The *shoulder-blade* is triangular, with one angle directed downward, one upward, and one outward, and it covers the ribs from the second to the seventh. It is not, however, attached to the ribs, but is separated from them by a cushion of muscle upon which it glides. At its external angle there is a socket for the bone of the arm, so shallow that this bone is not laid into it, but merely against it, an arrangement which is one reason of the frequency of dislocations of the shoulder-joint. The bone of the *arm* is single, attached above to the shoulder-blade, and below to the bones of the fore-arm. It has a large round head, which is united by a ball and socket-joint with the shoulder, capable of motion in every direction; and by a hinge-joint with the fore-arm, capable of flexion and extension. It has two projections, externally, and internally, just above the elbow, which give the breadth to this part of the limb, and to which the muscles of the fore-arm are attached. The bones of the *fore-arm* are two, the *radius* and the *ulna*; the former being on the outer side, and the latter on the inner. The ulna is connected chiefly with the elbow-joint, and the radius chiefly with the wrist; so that when a fall is received on the hand, the force is transmitted through the radius much more than through the ulna; and, hence, the radius is broken much more frequently than any other bone in the body. The ulna is articulated very firmly to the arm-bone, and moves on it in flexion and extension; it can be bent up very close to it, and may even be extended very nearly into a straight line with it. The radius is very slightly connected with the arm-bone, and has a round head received into a cavity in the outside of the ulna, while at its lower end it has a cavity in its inner side, which rolls round the small lower end of the ulna. The effect of this arrangement is, that the ulna has always the same face directed forward, while the radius can roll round the ulna, so that its edge, or even its back, can be turned forward, carrying the hand along with it. This motion is commonly said to take place in the wrist, but, in reality, the wrist has nothing to do with it. It is called *pronation* and *supination;* the hand is said to be *prone* when its back, and *supine* when its palm is turned upward or forward. It is in this motion that the greatest difference is observed between the fore-arm and the leg: had any such motion been permitted in the leg, it would have produced instability. The two bones are connected in their whole length by a strong membrane, which gives origin to muscles, while it does not interfere with the rolling motion. The two extremities of the ulna, both upper and lower, are readily felt in the living limb, and afford a very ready standard of measurement from the elbow to the finger points, called the cubit, from the old Latin name of the bone, *cubitus*.

The Hand consists of twenty-seven bones, and is divided into three parts, analogous to those of the foot. The solid part entering into the wrist-joint, is properly called the wrist, or *carpus*, corresponding to the *tarsus* in the foot, but for obvious reasons greatly smaller, both in itself and in relation to the rest of the hand. Five long bones come next, making the palm, and fourteen very moveable pieces superadded, complete the fingers and thumb. In its construction, the whole hand differs from the foot, on account of its being intended, not for support, but to catch with, and all its parts are adapted to this end. Eight small bones are pretty firmly united to form the wrist, presenting a ball superiorly to enter the cavity in the lower end of the radius, fitted inferiorly to support the bones of the palm, arched behind to give it strength, and concave in front to permit the bloodvessels, veins, and sinews, to run to the fingers, without being subjected to undue pressure. In the palm we see the principal difference between the hand and the foot. In the latter, all the bones of the instep lie in one direction, immovable, and serving only to rest on. In the former, four of the bones of the palm are placed side by side, to form the hollow of the hand, and to support the fingers; while another, supporting the thumb, is very moveable, being capable of being brought opposite the others, so as to grasp firmly anything between it and them. The pieces of the fingers are considerably larger than those of the toes, and much more moveable, but are formed on a similar model. The fingers have each three pieces, the thumb only two. The last piece of each is expanded at the end, to support the nail on its back, and on its front the delicate pulp where the nerves ramify, and in which the nicest sense of touch resides.

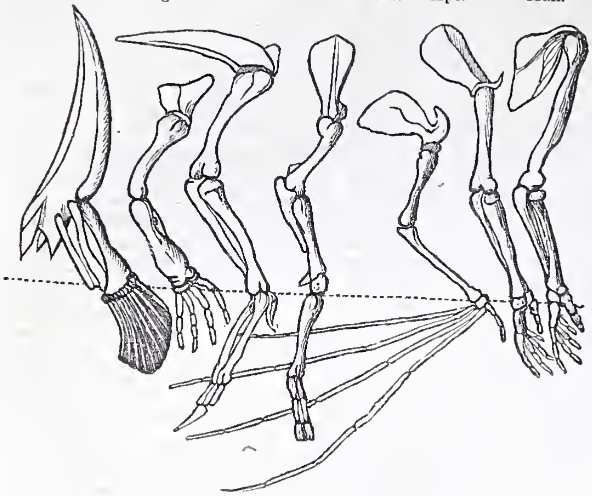



Front view of left Hand.

*c*, the eight bones of the carpus.
*m*, the five bones of the metacarpus.
*f*, the fourteen pieces of the fingers and thumb.

It is interesting to glance over the vertebrate division of the animal kingdom, and observe the modifications which an All-wise Creator has employed to fit the same bone or set of bones for different uses. The different genera whose fore-limbs are represented here, present very great differences; and to render these the more obvious to the reader, a line is drawn over the wrist-joints of each. In man, whose arm is to the left of the figure, and which we make our standard for comparison, the shoulder-blade

has the corner to which the arm is jointed, directed forward and outward, to let the motion of the arm be as free as possible,




while in the ape, it is directed more downward, because he walks on all his four hands. In the deer, and other quadrupeds, it is placed perpendicularly, because its only use now is to rest on the upper end of the arm-bone, transmitting to it the weight of the fore part of the body. In the bird and fish, it is elongated and narrow, because in them very little depends upon it. The collar-bone is not represented in any of the arms in the figure. We may remark, however, that while most perfect in man, it is wanting in most of the lower animals,—its use being to keep the shoulders separate, so that the arms may be crossed on the breast, to give a firmer point of resistance at the breast-bone, for anything to be pushed from, or pulled towards us, and to permit a free and sufficient extent of motion. Hence, it is found in those species only where the fore-limbs are much used for laying hold of objects, or for digging and scraping, as in the rat, the mole, the hedgehog, the squirrel, and monkey, up to man. In those who use them for scraping, striking, or tearing, though less freely, there is a loose bone like an imperfect clavicle, as in the cat, dog, bear, and lion. In those whose mode of swimming is by striking out, as the frog does, (for a frog is just like a man in his style of swimming), there are strong connexions between the shoulder and the breast-bone, serving for clavicles; and in birds, who strike out the same way in flying, there are strong clavicles fixed to the breast-bone so as not to allow of any motion, but to give very firm attachments to the wings. A clavicle would, however, have been worse than useless to the cow or the horse. When in running down a hill, we chance to fall on the hands or on the shoulder, one of the most common accidents is fracture of the collar-bone, because this bone is placed between the arm and the breast-bone, and consequently sustains a great part of the shock. But when a horse gallops down a hill, or takes a leap, no fracture is sustained, and yet the shock is greatly more violent. The reason of this is obvious from inspecting its skeleton, where we find that its fore-legs are not connected to the trunk by bones at all, but by immensely strong fleshy muscles passing from the ribs back to the shoulder-blades, between which the heavy body swings in safety.

The bone of the arm is in man longer than the fore-arm, which is not the case in any other instance in the figure. Its head is round, so as to permit free motion in every direction—while in most other animals its motion is confined—being limited in birds and most quadrupeds, to moving forward and backward, in the act of progression. In the fish it is very short in comparison to the rest of the member, which is, indeed, altogether very small in proportion to the rest of the body. The fore-arm in the ape has the power of rotation, as in man; and so it has in numerous animals who tear with their forepaws; and in the mole and ant-eater, who make their way by scraping and digging.

In the bird the radius and ulna lie parallel, and do not move upon one another; for there is no power of grasping enjoyed by it. In the bat, for the same reason, the radius alone reaches to the hand, the ulna ending in a delicate point, about half-way down. In quadrupeds, like the deer, which use the fore-leg only to rest on, the two bones admit of no motion; and in some they appear almost fused into one.

The bones of the hand vary very much, according to their offices in the different orders of vertebrate animals. The small round bones composing the wrist, are found with more or less modification in all. But the hand is formed perfect in man only. The ape, who comes nearest to him, has the thumb very short and weak, being scarcely longer than the metacarpal bone of the forefinger. In the bat, the pieces of the fingers are seen to be very long and delicate, for the membrane to be stretched on, which enables them to serve for wings. In the fish they are numerous, and placed close together, to form a fin. In the frog, for the same reason, they are webbed. In the bird they are few and short, while the metacarpal bones are long, to give support to the large feathers of the wing. In the quadrupeds with claws they are all placed side by side; and those who have hoofs, as the deer, cow, and horse, have but one or two, according as the hoof is single or divided, placed nearly perpendicular, and walk, as it were, on the points of their toes and fingers, the part of the hoof which rests on the ground corresponding to the edge of the nail.

In concluding the account of the skeleton, and of this particular part of it, I cannot recommend a more interesting work than the Bridgewater Treatise, by the late Sir Charles Bell, on "The Hand, its Mechanism and vital Endowments, as evincing Design;" in which the form, connexions, and relation to the rest of the body, and to the uses it is to subserve, are illustrated in a most beautiful manner, by comparison with the skeletons, limbs and habits of other vertebrated animals, both those at present existing, and those which have existed in former conditions of our globe, to whose state they were adapted. And I shall quote from him the following sentence, which he, in turn, quotes from Ray, an old writer:—"Some animals have horns, some have hoofs, some teeth, some talons, some claws, some spurs and beaks: man hath none of all these, but is weak and feeble, and is sent unarmed into the world.—Why? A hand, with reason to use it, supplies the use of all these."

The size of the skeleton varies very much, ranging from thirty-five inches to eight feet. The gigantic skeleton of the Irishman, O'Brien, preserved in the museum of the College of Surgeons in London, measures eight feet two inches. What is called the middle size in man, is about five feet four inches; in woman, about five feet. When the bones have been cleaned and dried, the weight of an ordinary male skeleton ranges from ten to thirteen pounds; of a female one, from eight to nine.

In early life, when their animal material preponderates in quantity (see p. 269), the bones are full of bloodvessels, and comparatively soft, flexible, and springy; and though liable to many serious diseases, they are very apt to escape the effects of injury. It is not common to meet with fractures in young children; and sometimes their bones, bending rather than breaking, suffer that partial fracture which has been compared to a "branch of a tree that yields to an attempt to break it while it retains its sap." The power of repairing injury is proportioned to the full supply of blood at this period; fractures are speedily re-united, and their effects so regulated by the subsequent growth of the bone, that permanent deformity is a very unfrequent occurrence.

The osseous system cannot be considered as being arrived at maturity until a period long subsequent to the age of puberty; most commonly somewhere between the twenty-second and thirtieth years. The bony tissue is now so constituted as best to answer its purposes in the bodily frame; it is now least liable to disease; and if fractures and other injuries be more frequent, it is only because individuals are now more exposed to them. The effects of such injuries are, in general, tolerably repaired; but if deformity be the result, it is permanent; because the bone has now ceased to grow. As life advances, the osseous system undergoes many obvious alterations. The shape of some bones is altered, and the texture of all is somewhat changed, with an increase in the earthy material over the animal constituent—so that fracture is more apt to happen to the bones of the aged, from even a less serious fall or twist.

When fracture has taken place, if the bone be kept at rest, the *fibrin* of the blood is poured out around it, from the small bloodvessels which have been torn. This fibrin attaches itself to the periosteum round the fracture, enclosing it as in a bag.

On the inside of this bag, and on the outside of the bones, new bony matter is deposited from the blood, and, by and by, the fracture is enveloped in a ferule of new bone—which bony matter is also formed between the broken ends, cementing them directly together. This sort of ferule is felt as a lump on the bone, for a long while, but as the direct connexion of the broken ends becomes stronger, it disappears, being now less needed. The bones of the upper extremity are generally united in three weeks, those of the leg in a month, and the thigh-bone in about six weeks; but even at these periods they are not so strong as to bear rough usage.

When a bone is broken, it must be obvious that the muscles will no longer produce the natural action which the bone served to direct, but will draw the piece that is broken off into some place where it ought not to be. When the thigh-bone is broken, for example, the strong muscles which pass along it from the pelvis to the leg, pull up the lower fragment, so that the limb becomes shortened. It is also apt to be distorted, by the loose piece being pushed by violence, or pulled by the muscles, to one side or the other. In treating fractures, we begin, therefore, first to reduce them, or bring the broken ends into their proper places, and then we have to maintain them in apposition, by the application of splints and bandages, which will keep them immovable till union shall have been obtained.

When there is no wound accompanying it, a fracture is styled *simple;* when a wound passes down to it, so that there is a communication between the broken ends of the bone and the external air, it is called *compound,* and becomes a very dangerous matter. A compound fracture takes many weeks, or even months, to mend; and frequently it will not mend at all, but causes a profuse suppuration, so that the limb must be amputated, to give the patient even a chance of surviving.

Sometimes we meet with defective states of the nourishment of bone—so that it becomes very brittle or very soft. In the former case, fractures will happen to almost every long bone in the body; in the other, they bend under the weight of the limbs, causing great deformity; and sometimes, after this deformity has taken place, they become unnaturally hard, producing, of course, deplorable and incurable decrepitude.

Ulceration and mortification take place in bones, as well as in the soft parts; and a very curious affection occurs, called *necrosis,* when a bone dies, and a new one grows round about it, to supply its place, after which the old one is thrown off, or, more commonly, requires to be removed by the surgeon. Scrofulous diseases of the bones are very common, and give much work for the surgeon: other constitutional affections attack them also. Several forms of cancer, and other incurable changes of structure analogous to it, also attack bones; and death can be avoided only by the removal of the whole bone affected.

## ON THE MANUFACTURE OF CAST-IRON.

### CHAPTER III.

#### ON THE USE AND THEORY OF THE HOT BLAST.

In the former chapters we endeavoured to show that the irregularities of the blast-furnace arose partly from atmospheric changes in the volume of the air, and partly from the construction of the furnace itself, by which a portion of the metal, in falling through the blast, becomes oxidized; and as a portion of the blast comes into direct contact with the incombustible matters of the charge, and the intensely heated sides of the hearth, it may become so much rarefied as to be rendered unfit for supporting the combustion of the coke, or even for decomposing the carbonic oxide. The vitreous matters, likewise, being chilled and solidified by the rush of cold air, prevent the free application of the blast upon the fuel. These obstructions, also, cause the focus of combustion to shift from place to place in the furnace, and by this means a portion of the metal becomes prematurely melted down, while only in the state of steel or hard cast-iron; while in the part of the furnace where the blast is obstructed, scaffolds are produced. These again by giving way form new openings for the blast; and, at times, they even choke up the tuyères altogether, from the quantity of fluid metal brought down along with them, to the great annoyance of the furnace-keeper. All these evils might be lessened, if not entirely avoided, by an alteration of the furnace; for, by keeping the ore longer in a state of cementation, and by applying the blast to the fuel in a diffused or gentle stream, as is done in the air or pit furnace, the combustion would be more perfect, and the heat more uniform.

We shall now advert to the use of rarefied air, or the hot blast, as it is called. In 1804, hot air was tried at the Bradley Iron Works, in the smelting of iron, but was given up in consequence of the puddlers complaining that, since the hot air was used, the iron had become so rich and gray that it would not answer for puddling, and they could make nothing of it. After using it for about three months it was abandoned, as the iron produced by it was unsuitable for their purpose—it being forge pigs, and not foundery iron they wanted. In 1817, Mr Stirling, an ingenious gentleman, belonging to Ayrshire, took a patent for a means of economizing fuel by retaining the waste heat that is constantly escaping from furnaces, by means of the fresh air with which the furnace was afterward to be supplied; conceiving that, by this means, more heat might be obtained from the same consumpt of fuel, by the caloric accumulating in the furnace, which he considered would at least be equivalent to the difference of temperature imparted to the blast, above the temperature of the atmosphere. However, from the necessary expense of the erections for retaining and transmitting the heat to the fresh air, and the small amount of saving likely to be derived from it, this patent never was brought into use. Akin to this is another patent of a still more recent date, to which the patentees have given the name of *hot-blast,* and which has now been adopted by most of our Scottish smelters. From the vague manner in which this specification is drawn out, it is perfectly impossible, without the aid of a letter of the inventors to Dr Cleland, to discover in what they consider the invention to consist. However, this letter and Professor Clark's paper give us a clue to the whole, especially as these are also confirmed by the belief of the smelters who have adopted it. This invention, therefore, may be considered—1st, as a means of increasing the velocity of the blast without a corresponding increase of power from the blowing engine; and this, the patentees seem to imagine, can be effected by expanding the air by heat after it has left the blowing cylinder; 2nd, that by this heating of the air before applying it to the support of combustion, they seem to think that the combination with the fuel must be more rapid; and, that by this means, they can produce a much more intense heat in the hearth of the furnace than when cold air was used. "Because," say they, "from the enormous quantity of air required for the support of combustion in a blast furnace, it must absorb and carry off a great proportion of the heat; and, therefore, from the heat in the air, and the increased energy of the combustion, less fuel should melt the ore with the hot than with the cold blast." And, in proof of the efficacy of their invention we are told, that when they heated the air to 300°—for which they required 8 cwt. of coal for the heating process—they obtained such an increase of temperature in the furnace as would have required 58 cwt. of coal, or $7\frac{1}{4}$ times the quantity to have been consumed in the furnace itself with the cold blast. And, again, when they raised the blast to 600°, 8 cwt. of coal, consumed in the heating furnace, produced a saving of 116 cwt. in the large furnace. However, as the patentees seem to have forgotten that air expands in all directions, their first idea of increasing the velocity of the blast, without increasing the resistance against the piston, appears to me to be altogether erroneous. And, again, that 8 cwt. of coal, when consumed in a separate furnace, should be capable of generating so much heat in the large furnace—and this too in a detached building situated at some distance—and, at the same time, that such an increase of heat could have been produced by blowing the furnace with the same pressure of blast, and from the same orifices, or nozzles, as were used with the cold blast, but, now, with air rarefied to half an atmosphere; or, in other words, by discharging into the furnace a blast only equal to half the quantity that was used in the state of cold air; but now expanded to the same volume as the cold blast—the very means by which combustion in the large furnace ought to have been rendered still more gentle and diffuse—is an idea so un-

philosophical, as at once to create a doubt that this supposed increase of heat in the furnace does not take place; and that they must be in error here also. Again, from Mr Dunlop's table in the appendix to Professor Clark's paper, it is there stated that, with the cold blast, the weekly consumpt of fuel was about 3 tons 12 cwt. of coke, while, when the air was heated to 300°, about 2 tons 7 cwt. sufficed; and with four furnaces, and the air heated to 600°, only 2 tons 5 cwt. of green coal, in place of coke, were used to the ton of iron. In page 6, we are likewise informed that, during the successive periods specified, the same blowing apparatus was in use, and the furnaces at Clyde Iron Works, which were at first three, had been increased to four, and the blast machinery being still the same, &c. And, in the last page of the appendix, the blowing engine has a steam-cylinder of 40 inches diameter, and a blowing cylinder of 8 feet deep, and 80 inches diameter, and goes 18 strokes a minute. The whole power of the engine was exerted in blowing three furnaces, as well as in blowing four; and, in both cases, there were two tuyères of 3 inches diameter to each furnace. The pressure of the blast was $2\frac{1}{2}$ lbs. on the square inch. The engine then went less than 18 strokes a minute, in consequence of the too great resistance of the materials contained in the three furnaces to the blast in its passage upward. These statements being quite at variance with the known laws of the elasticity of air, to conceive that, with a uniform pressure of $2\frac{1}{2}$ lbs. to the square inch, the same quantity of air should be discharged through the same orifices when expanded to more than double its former volume, at once awakened my suspicions that they must be deceiving themselves with this also; and, at the same time, it seemed to afford me a key to the whole of the mysteries of this saving of fuel by the use of the hot blast. However, before saying anything more on the subject, I resolved to see some of the smelters, and hear their opinion of this singular and obvious overlook in the appendix. On calling their attention to it, I was not a little surprised to find that this was their opinion also, and that their blow-pipes were still of the same size as when they were using the cold blast—that the pressure they used was still the same—that their engines were wrought at the same speed as formerly—and that they were not letting any of the blast escape—neither was there any extra leakage in the heating apparatus, at their works, so far as they were aware.* Indeed, I found that all with whom I spoke believed it to be the case, as stated in Professor Clark's paper. However, as I knew this to be impossible, I again pressed the question on one of the most scientific of the gentlemen, and he admitted that he had taken the patentees' word for it: he had made the same objection to them when it was first spoken of, but was assured of its being a curious fact, that the dilating of air by heat made no difference whatever in this respect. As I considered the assertions of a sanguine or interested patentee no authority, he then, by way of convincing me, observed that, perhaps, air at a high temperature might be like a sponge full of water, which was much easier squeezed to half the size, than to squeeze it dry; and, therefore, he considered it would take little or no more power to force air through the same aperture at 600°, than when cooled down to 32°. Whether this also was the general belief of the smelters I did not stop to inquire. At any rate I found they all approved of the use of hot air, although they admitted that they could produce no more iron with it, than the English smelters did with their cold blast, from the Scotch coals not being so durable; neither could they produce quite the same results as were stated of the Clyde Iron Works. Still, they could now use green coal, which they said they could not do with cold air, because they found that when any of their heaters gave way, and they were obliged, for a time, to have recourse again to the cold air with the green coal, their iron became hard, and inferior in quality, by the furnace becoming lower in temperature, from the want of the extra heat afforded by the hot blast. And, in proof of this opinion, they asserted that, it is want of heat alone that causes the furnace to produce bad iron; for in damp weather, say they, combustion cannot go on with the same energy, and therefore the furnace must become cooler, and the iron hard. And they asserted also, that the hot air must, to a certainty, increase the heat of the furnace, and therefore they concluded that the iron must be good from the use of the hot blast. Another reason they gave in favour of it is, that their furnaces are more easily managed, not being so liable to choke and form tuyères across the hearth—or brigg up as they call it—and they complained of the heating apparatus being a great additional expense. And further, they thought that something is gained from less power being necessary to blow the furnace with the hot air, because they conceived that the increasing expansion of the air as it passes along the pipes, makes it rush into the furnace from the blow-pipes with a much greater velocity than the power of the engine could impel it with.† However, since the smelters seem quite satisfied with these explanations of the effects of hot air, although in direct opposition to the known laws of temperature and elasticity of the air—we shall leave them to their own opinions and return to their furnaces—and although rather unwieldy eudiometers to experiment with, still, we may discover from them how far this heating of the air will affect their rate of combustion, and also how much air has been used from the quantity of fuel consumed. For it must be evident that if this heating of the air increases the heat of the furnace so wonderfully, it must likewise accelerate the rate of combustion of the fuel also; and, therefore, if they are right, a greater quantity of fuel must be consumed in a given time by the hot than by the cold blast, and since the combination of the oxygen in the blast, with the coke, is the sole cause of its disappearing, or sinking down from the tunnel head, to replace that which has been consumed; therefore, this consumpt of the coke will afford us a means of determining the quantity of air that has been blown into the furnace in any given time also. Now, from the data furnished to Professor Clark by the patentees, from the work belonging to one of themselves, and therefore under their own immediate inspection, we find that the successive weekly consumpt of fuel put into the three furnaces at Clyde Iron Works, was as follows (the blowing machinery being still the same):—

| | Tons. |
|---|---|
| With the cold blast, | 403 |
| With blast heated to 300°, (expanded about $\frac{1}{2}$ more in bulk), | 360 |
| With the blast heated to 600°, (or expanded to fully twice the bulk), | 188 |

this last being about the quantity of coke contained in the 416 tons of green coal, which is the proportion for three of the furnaces. Now, if we allow a little for the loss of heat by radiation and the imperfection of their first heating apparatus—which they acknowledge to have been imperfect—the consumpt of fuel

* In these conversations with the smelters, I observed that, since this was the case, they must only be using one-half of their former blast, and that it should be called half-blast and not hot-blast, as it was the want of air that saved the fuel—but this they would not admit. However, in the autumn of 1837, (after I had read this paper,) I again met two of them, and the conversation turned upon it. They now admitted that I was right after all as to the hot air being only a half-blast; because, with the same cylinder, they were now blowing more furnaces with the hot, than they formerly could do with the cold air. And they laughed heartily at a singular explanation of this mystery, afforded by the answer of an engine-keeper of a neighbouring work, whose manager was a great advocate for the hot-blast; when asked by one o their engine-keepers how he managed to keep his engine so regular,—he replied, Oh, I just let off the spare blast *quietly*; 'tis by far the best way of regulating the blowing-engine when she is overburthened at any time, just to let off the spare blast till she comes to her proper speed. I shall just mention another proof drawn from Clyde Iron-Works itself. Having visited this work in 1840, to see their new blowing-engine, along with a young friend who had been engaged in its erection; as I had previously explained to him my views of hot-blast, to show him I was right, I put the following questions to the engine-keeper. What is the use of heating the air? Oh, 'tis to make the furnace hotter; so much cold air in the cold blast cooled the furnace very much. Did you ever attend a cold-blast engine? Yes, for four or five years. Does it make any difference upon the engine to blow the cold or the hot blast furnaces? Oh, yes, it makes a great difference; the hot is much easier blown than the cold; the same engine that could only blow three furnaces with the cold, can now blow five with the hot. And with the same blowing cylinder? Yes, with the same blowing cylinder, she can now blow five, while she could only blow three with cold-blast. Then could you tell by the working of the engine, if the fire-men, at the furnaces for heating the pipes, were neglecting their fires, or letting their pipes become cool? Yes, I can tell when they neglect any of their fires; but I cannot tell which it is till I go and see. How do you know by the engine? Because she goes quicker; sometimes she will make two strokes a minute quicker.

† Having had occasion to call upon an engineer, I found him engaged with a smelter, who was relating to him the following as a very curious experiment he had just made:—We were getting a new set of heaters for one of our furnaces, when I caused a small hole to be drilled through each pipe, just at the top of the bend, so that I might test the pressure in each. After they were in full operation, I tried each pipe with a pressure guage; and strange to say, I found the pressure the same over the whole of them—it was quite the same in each pipe. My friend remarked rather drily, I think you might have expected that. Well, said he, I can assure you it is the general belief in the trade, that the pressure is different in each pipe, and that it continues to increase as the air becomes heated in its passage through them, until it gets off at the nozzles; but this is not the case after all, although it was upon this principle the patent was taken out. And it was just because I had some doubts about it that I resolved to try it, and now I find it is not so.

comes out exceedingly near the proportion of air that could have passed through the tuyères at the respective temperatures. Thus, if to consume 403 tons of coke required about 2898 tons of air then 360 tons of coke would require about 2588 tons of air also; but, from being expanded, only about 1932 tons at the temperature of 300°, could have passed through the tuyères; therefore the air either must have been cooler when it reached the tuyères, or the pressure must have been rather more than the $2\frac{1}{2}$ lbs.; both of which are very likely to have been the case, as they admit the engine to have been overburthened in 1830. However, in 1833, after they had acquired a little more experience in the management of it, with the air heated to 600°, the 188 tons of coke would have required about 1350 tons of air; now, even at this elevated temperature, about 1305 tons of air only would be discharged at that pressure, which last is as near an approximation to the quantity necessary to consume the fuel as possible; and to half the quantity of air which was discharged into the furnace by the cold blast, especially when the heat ranges from 530° to 550°. Now, if this heating of the air facilitates the combustion, and by this means increases the temperature of the furnace, as its advocates affirm; and if the same quantity of air likewise was discharged into the furnace at 600°, as when the cold blast was used as they also assert; then, since 403 tons of coke were consumed weekly by the cold blast, certainly, from this increased energy in the combustion, a much greater quantity ought to have been consumed by the use of the hot air. But how stands the case? Only 188 tons are consumed weekly when the blast is heated to about 600°; therefore, we are fully warranted in concluding, that they are in error here also, and that only 1350 tons of air must have passed through the tuyères, after all. For, if the 2898 tons had issued from the tuyères, as in the case of the cold blast, by the application of so powerful a blast upon such a scanty supply of fuel, the whole of the contents in the furnace would very soon have become exhausted; and, by the end of the week, the furnace would have been completely blown out, in consequence of the inadequate supply of materials. And, therefore, from the correspondence between the weekly consumpt of fuel in the furnace, and the actual quantity of air that could pass through the blow-pipes, agreeing so nearly,—we have a most unquestionable proof, that both the patentees and the smelters are labouring under a most egregious mistake, in supposing that the few degrees of heat, imparted to the air, could produce any material increase of heat, or any effect whatever in the progress of combustion, except the efficacy it possesses of diminishing the supply of oxygen, and thereby *diminishing the intensity of the heat* in the hearth of the furnace also; because, from the air being expanded to double its volume, it would have required nearly double the time to pass through the same orifices. Let us just reverse the case. Suppose we could cool the air down to 500° below the mean temperature, then, from its volume being reduced one-half, in this case the same power would force it through orifices of half the area of the present blow-pipes, or would force twice the quantity through the present orifices. In the latter case, this dense air containing twice the quantity of oxygen, the fuel would be consumed in one-half of the time, and therefore twice the quantity of heat would be evolved that would be evolved from air at the mean temperature, and four times the quantity of heat that the air heated to 800° would give out. *Such then would be the efficacy of a cold blast*—so that by their heating the air they actually diminish the energy of the combustion, and the intensity of the heat in the furnace also. The melting of the cast-iron linings of the tuyères is no proof whatever of an increase of temperature, since these linings melted so frequently, even when they were cooled and protected by the stream of cold air rushing over their surfaces. Another illustration of this principle may also be given in the old experiment of placing one candle under the receiver of a condensing syringe, and another under the exhausting receiver of an air-pump, to show that as the air increased in density in the one case, the flame became brighter and brighter; while in the other it became feeble, languid, and dull, in proportion as the air became rarefied. The latter effect was also experienced by Marco Palo, on the summit of a mountain in Central Asia, and by Humboldt on the Andes. When these travellers had attained the elevation of 18000 feet above the level of the sea, they found the greatest difficulty in kindling and maintaining their fires, from the extreme rarity of the air, which at that height is just about half an atmosphere—being just about the same density as the air that the hot blast furnaces are supplied with. In other words—were the cold blast furnace to be erected upon the summit of the Andes, it would be placed in precisely similar circumstances, with regard to the supply of air, as the hot blast furnaces at present are (minus the 550° of heat). Now, can we, for a moment, conceive that combustion would be accelerated, or that a furnace placed on such an elevated situation would be hotter in the hearth than a similar furnace placed at the level of the sea? Therefore, to have obtained the full effect of the additional 550° of heat, in increasing the temperature of the furnace, the air ought to have been kept at its present density; and both the blast, and the furnace also, ought to have been wrought under the pressure of an additional atmosphere.* I will just give another illustration to show that a greater heat is produced in the cold blast furnace than by the hot blast. The intensity of the heat, in a furnace, depends not only on the quantity of fuel consumed in a given time, but also on the means that the furnace possesses of absorbing and retaining the heat, after it has been liberated from the fuel. Now, if we take the rate of consumpt—say per second of time—and also the number of degrees of heat which that quantity of fuel would impart to water, we will obtain something like a data to go by; although we can form no idea, by this means, of the precise degree of heat in the body of the furnace itself. Now the three furnaces, when blown with cold air, consumed 403 tons of coke, being just about the rate of $\frac{1}{2}$ lb. per second of time to each furnace; then suppose this $\frac{1}{2}$ lb. of coke would impart to water—say 7000 degrees of heat—then 7000° of caloric must be liberated every second of time in the hearth of this furnace, which would afterwards ascend and be absorbed by, or deposited in the materials of the charge. Now, when the blast was heated to 600°, we find the consumpt reduced to 188 tons per week, therefore, only about $3\frac{3}{4}$ oz. were now consumed per second in each furnace. This quantity could only impart to water about 3281°; then, if to this we add 540°, as the heat of nearly $\frac{1}{10}$th of a lb. of coal consumed in heating the air, we will have 3821° of heat evolved; but as a considerable waste of heat must take place, both by the chimney of the furnace for heating the pipes, and also by radiation from their surface—one-half only, as the available heat, may be added to the 3281° evolved from the fuel in the hearth. Therefore, 3551° will probably be the maximum of the heat generated, per second of time, in the hearth of the hot blast furnace. And since the heat or caloric which is liberated per second in these furnaces appears to be in the proportion of about 7000° with the cold air, to 3551° with the hot; therefore the heat of these furnaces, I should imagine, must be nearly in the same ratio, whatever may be the opinions of the advocates for hot blast.

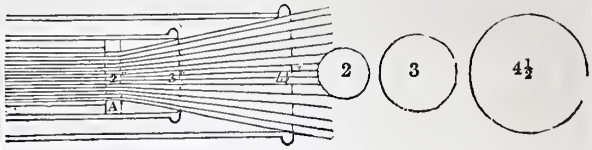
This economy of fuel in the blast furnace, therefore, appears to have originated with the smelters, and to have been purely accidental after all; the patent which gave rise to it being altogether erroneous in principle, and founded entirely on a few inconclusive experiments, originating apparently in very singular and mistaken views, which the patentees seem to have entertained about the nature of expansion, and the elasticity of air by heat. For they seem to have imagined it possible to expand the air to double its volume, during its passage from the cylinder to the tuyères, without its recoiling backward and reacting against the piston,—just as if it had been a non-elastic body—and they also seem to have thought, that the same quantity of air might be discharged through the same nozzles or tuyères into the furnace, with the same pressure of blast when it was expanded to double its bulk, by being heated to 600 degrees,

* Soon after the discovery of the astonishing heat produced from the oxy-hydrogen flame, it was anticipated that it might be still farther increased by condensing the compound gases, and for this purpose the oxy-hydrogen blow-pipe, as it was called, was constructed. By this means the compound gases were compressed into one-fourth or one-fifth of their former bulk previous to burning, by which they expected that the heat of the flame might be quadrupled; but they soon discovered that the moment the gas issued from the orifice it expanded to its former bulk; and that, to obtain this increase of heat from the dense gas, the jet of flame must also have been burnt under pressure; that is, if five atmospheres of gas had been injected into the chamber of the blow-pipe, and the jet burnt within another chamber under the pressure of four atmospheres, then the heat of the flame might have been quadrupled, but not otherwise. So it is next to impossible to increase the heat of a furnace by heating the air, unless by an enormous increase in the power of the blowing machinery, or, like the oxy-hydrogen blow-pipe, by putting both the blowing machinery and the furnace under the pressure of an additional atmosphere, which is physically impossible.

as when the cold blast was used. However, after all that has been said and written about this invention, it appears to be nothing more than an indirect means of reducing the quantity of the blast, and by this means reducing the consumpt of their fuel, which the smelters themselves accidentally stumbled upon, while they were vainly attempting to put the patentees' suggestions into practice, with the view of obtaining from them an increase in the heat of their furnaces;* and this saving of fuel the smelters also unconsciously effected, by their unwittingly reducing their blast to half the quantity they were in the habit of using when cold—from their still employing the same pressure, and the same tuyère pipes with the expanded air which they formerly did with the cold blast, in conformity with the patentees' instructions.

Now, had either the smelters or the patentees clearly understood the nature of combustion, and the laws that regulate the expansion of the air by heat, they would undoubtedly have adjusted the size of the blow-pipes to the increased bulk of their air; and, in that case, the result upon their furnaces would have been very different indeed. However, having overlooked this law of expansion altogether, they were astonished at this diminution in the consumpt of their fuel with hot air, especially when they also discovered that about the same weight of green coal was now sufficient to reduce the ore; and they then naturally enough ascribed it to this supposed increase of heat, from an increased energy in the combustion, arising from the heat in the air. Now, had the smelters clearly comprehended what they were about, or had they at all understood the subject, they too might have patented this principle for prolonging cementation, as a discovery of their own; and they might have adopted this heating apparatus also, which at present serves no other purpose in the economy of the furnace, than to reduce the combustion, by keeping back one-half of the air, and allowing the other portion to produce a soft and diffused blast upon the fuel, like what is obtained by the use of a grate or bars; or they could have produced the same effect from the cold air, by allowing one-half of the blast to escape, and withdrawing their blow-pipes a few inches, until the expanding stream of air would just cover the same surface of the fuel, as the hot blast did; or, by reducing the apertures of the blow-pipes from 3 to 2 or $2\frac{1}{8}$ inches, by a ring or perforated disk, inserted about a foot from the present orifices; since any of these alterations would have had precisely the same effect upon the combustion of the furnace as their patent heaters—minus the few additional degrees of heat carried in with their blast—and this also they might have obtained, and at a much cheaper rate by employing Mr Stirling's plans for economizing the heat. By adopting the first of these suggestions, the engine would have been relieved of one half of her burthen, and the spare blast from both might have been employed to blow another set of furnaces. With either of these simple alterations, and Mr Dixon's discovery of the applicability of green coal as a substitute for coke, a considerable saving might still be obtained, even over those who use the hot blast.†

I shall now offer a few general observations, which will be better understood by a reference to the illustrations given in my last paper—see pp. 449, 450. The following fig. shows the




relative sizes of the blow-pipes that with the same pressure would discharge equal quantities of air. The 3 inch aperture is the size for air at the mean temperature, and the $4\frac{1}{2}$ when heated to 600°; because, the $4\frac{1}{2}$ being about $2\frac{1}{8}$ times the area of the 3 inch, this is the size which ought to have been adopted when the air was heated to 600°, since this increase of temperature would expand the air to $2\frac{1}{8}$ times its former bulk. Not having attended to this, when experimenting upon the effects of the hot blast, their experiments therefore can only be estimated as being equivalent to the 2 inch aperture with the cold air. Again, this least size, or the 2 inch tuyères, ought to have been substituted by the smelters, when they were obliged to have recourse for a time to the cold blast; because, by their still continuing to use the same 3 inch tuyères with the cold air also, the quantity that would pass through them would be precisely the same as if they had substituted the $4\frac{1}{2}$ inch size for their hot blast. Now, it must be evident, that such an increase of blast must have produced a corresponding increase in the combustion of the furnace; and therefore, since the melting point of iron is just in proportion to the carbon it contains; and as the materials of the furnace are in different stages of cementation from the last-put-in ore to the melting iron; and as the soft cast-iron melts with a lower heat than the harder kinds; and as these last melt with less heat than when in the state of soft steel; and as soft steel melts with a lower heat than hard steel, while that which is in the state of malleable iron will not melt at all, but will only soften and become like plastic clay, but will never become fluid, until it has passed into the state of steel; therefore, the materials in the furnace may be considered as consisting of a series of stratifications,—the lower part being coke, from which the iron has already been melted out. Above this—if the furnace is working regularly—is the coke, with the soft cast-iron in the act of melting—above this again, is the coke mixed with the hard cast-iron, which is still absorbing carbon, and passing into the state of the soft—above this, steel passing into the state of hard cast-iron—above the steel, malleable iron also uniting with the carbon of the coke, and passing into the state of blistered steel—then above this, the ore in the various stages—which we have already noticed among the roasted ore—passing into malleable iron. Now, as cementation is rather a slow process, and cannot be accelerated by any undue increase of the heat, but must be allowed time for the regular combination taking place; therefore, the consequence of their increase of blast by substituting the cold air, would be a corresponding increase in the combustion; by which means, the furnace would soon become so hot, as to melt down the whole of the hard iron, and perhaps that part which had passed into the state of steel also, thereby producing a very bad iron indeed, from the mixture of the steels and the hard and soft irons all being melted and blended together by so sudden an increase in the heat of the furnace. And this also shows that a great heat in the smelting furnace is not necessary to produce soft iron—as the smelters imagine—but on the contrary, that the hottest part of the furnace ought never to be much above the melting point of soft cast-iron; otherwise, the harder kinds will be in danger of being melted down before they have absorbed a sufficient dose of carbon; and it likewise shows that the quality of the iron is also influenced by the quantity of the blast and the manner of apply-

* To have obtained this additional rise of 550 degrees of temperature, from the 550 degrees of heat in the air, the blast must have been prevented from expanding, until it was applied to the surface of the fuel; or it must have been again compressed to its former volume by the blowing machinery. To do this, however, would have required a blowing engine, with nearly six times the area of a steam cylinder, to those at present in use; or their blowing engine, with a 40-inch cylinder, would in that case require to have been replaced by an engine with an 8-feet steam-cylinder, to overcome the elasticy of the air that 550 degrees of heat would impart to it, so as to discharge the blast upon the surface of the fuel at the mean density of the atmosphere.

† Much has been said about the inferiority of the iron produced by the hot blast,—many of the founders and machine-makers asserting that it is greatly inferior to that produced by the cold air; while the reports of experiments and analyses would lead us to believe that there is no greater difference, after all, between the hot and the cold-blast iron, than might have been expected from iron manufactured at different works, or from different varieties of ore. However, having procured several castings of soft hot-blast iron, from a foundry where cotton machinery is cast, I was certainly astonished at their weakness and want of tenacity, being little stronger than type metal; and, when turned or filed, there seemed to be a considerable quantity of loose, shining, scaly matter, throughout the mass. Indeed, it had every appearance, both in fracture and the wrought surface, as not being pure cast-iron, but a compound formed of cast-iron and sulphuret of iron, melted together. Now, this might easily take place from too great a heat in roasting the ore, melting some of the sulphuret into a black slag, (as the copper smelters well know, and guard against with the utmost caution with their ores,) because, if the sulphuret once melts, the remaining sulphur can scarcely ever be driven off from it afterwards, and in this state it readily combines with the fluid metal and deteriorates its quality. It may also be produced in greater quantities in the hot-blast furnace, from the green coal containing sulphur; whereas, in the cold-blast furnace, coke alone is used; and also from double the quantity of air passing upward through the materials of the charge, the remaining sulphurets and other unstable matters will be more readily decomposed and carried off in this furnace; and therefore the metal ought to be both purer and stronger, and altogether of a better quality, from the cold, than from the hot-blast furnace. Perhaps the quality of the hot-blast iron might be improved by substituting for the green coal, the same proportion of coke that the green coal contains; for it must be obvious that the coal must be reduced to the state of coke near the tunnel head, and therefore it can only be the proportion of coke it contains, that can be available in reducing the ore.

ing it, and not by the extra proportions of fuel; because, if the quantity of fuel is just sufficient for the cementation, and afterwards, to supply heat enough to melt the soft cast-iron when formed, this is all that is requisite. For, supposing that double the quantity of fuel were to be added to the charge, matters would still remain the same; because no more carbon would be taken up than sufficed to make the iron fluid, while the remainder of the fuel would just require an extra time for the blast to consume it out of the way, to allow the rest of the metal, which had arrived at the state of soft cast-iron, to get down to the melting point of the furnace also. We now perceive the real use of the extra quantity of fuel which the smelters put into the cold blast furnace when foundery iron is to be made, as this can neither combine with the iron nor increase the heat, since the rate of combustion is regulated by the blast alone. Its use, therefore, must just be, to afford a longer time for the cementation, during the period that the blast is consuming this extra fuel out of the way. So also, by the use of the hot blast the same thing is effected, although in a very different manner. From their unwittingly only using one-half of their former quantity of air, the materials are just kept as long in a state of cementation with about half the quantity of fuel, as they formerly were, when double the quantity was consumed in the same period of time, by the cold blast,—clearly showing, that it is a sufficient time for the due cementation of the materials, and not an extra heat, that is wanted to produce the soft iron; for, had the hot-blast smelters allowed the full blast to enter the furnace, by adopting the 4½ inch tuyère pipes with the hot air, in that case their furnaces would have consumed just as much fuel, and produced iron of a similar quality as they formerly did with the cold blast. The only effect from the heating of the air would have been getting rid of the obstructions that form about the tuyères, from the chilling of the slag. However, if more attention were paid to the application of air to the furnace, in the state of a diffused or a soft blast, a slower rate of combustion, and a still farther saving of fuel might be effected; for we see that if only a small quantity of coal is added to the blackband ironstone for the purpose of roasting it, this ore is frequently reduced to the state of malleable iron or steel—a proof that a much lower heat than that of a blast furnace would reduce the ore, and a much smaller quantity of fuel also would suffice, if properly applied with a corresponding quantity of air; and also, that the cold-blast furnace, by these changes, might be rendered as effective, and as easily managed as the hot blast, and with much less expense.

Figs. 4 and 5,—the cupolas of a parabolic form, with the small arches over the tuyères, to allow the blast to diffuse itself more freely upon the surface of the fuel, and also to supersede the more fragile tuyères of slag, which are so difficult to keep at a proper size. The perpendicular lines may be supposed to represent the action of gravity upon the materials of the charge, and also the area in superficial feet, and the distribution of heat at the respective heights in the furnace; while the radiating lines also represent the diffusion of heat throughout the mass, from the focus of combustion; and they show at the same time the direct tendency of the whole of the materials to slide downward into that focus, from the peculiar form of the interior of this furnace. The dotted curves, in figs. 2 and 5, are intended to exhibit the progressive sinking downward of the charge in the respective forms of furnace at the end of every 5 hours. In Fig. 2, from the small space near the tunnel head, the charge will sink much quicker down into the hotter parts of this furnace—during the first 5 or 10 hours—than in Fig. 5, where the charge will remain near the top; and by this means, the sulphurets and arsenurets will be decomposed, and the sulphur and arsenic will be much more perfectly volatilized and driven off, when kept in a moderate but continued heat, than in the former, where the compounds will be liable to be melted and run down, and thereby deteriorate the quality of the iron, by combining with the metal in the hearth; and, from the greater length of time that is afforded for cementation in a furnace of this construction, the metal ought to be softer, and of a better quality also. These curves will also serve to illustrate the progress of cementation going on in the furnace,—assuming the materials to sink through one of these spaces in about 5 hours; as the smelters say that the charge occupies about 48 hours in its descent from the tunnel head to the hearth.

In Fig. 2, the 1st division, or 5 hours, the ore, at a bright red heat, has become very soft and spongy, from tho gaseous matters escaping.—10 hours, arrived at the state of black oxide, and beginning to arrange itself into small crystals, or shooting into spicula, and assuming the fibrous structure of malleable iron.—15 hours, malleable iron absorbing carbon, and passing into the state of blistered or hard steel.—20 hours, hard steel becoming soft, or as cast steel.—25 hours, soft steel passing into hard cast iron.—30 hours, hard cast iron becoming soft cast iron.—35 hours, soft cast iron melting and running down.—40 hours, coke in a high state of incandescenee, with the metal and flux gliding down amongst it, in their passage to the hearth.—48 hours, the focus of combustion.

Fig. 5. The parabolic furnace, with a heater on Mr Stirling's principle, for economizing fuel, by seizing the waste heat that escapes from the top of the furnace, and returning it again with the fresh blast. The cold air enters by the pipe in the centre, is conducted down, and made to impinge directly upon the bottom; it is then forced to radiate or spread itself outward along the surface of the metal, by means of the sheet-iron lining; after which, it escapes by a pipe carried down a recess in the building to the tuyères, as represented by the arrows. I shall now conclude with the form of a specification on scientific principles, which any of the smelters might have patented, for producing precisely opposite effects upon the smelting furnace, to any thing ever contemplated by the patentees in their patent.

*Specification of a Patent granted to*
*for Improvements in the Application of Air to Smelting Furnaces*:—

Now know ye, &c.,

That my improvement consists in the application ot the air to the fuel, not with the violence of a tornado, as heretofore, but in the state of a soft, a diffused, or a rarefied blast, so as to enable me to reduce the temperature of the furnace as near as possible to the melting point of the kind of iron I wish to produce. By this means I can obtain iron of any quality, and with a saving of nearly one-half the fuel formerly used. Thus, when I wish the furnace to produce foundery iron, I reduce the quantity of the blast—always taking care, however, still to apply the air to as large a surface of fuel as possible, until the temperature of the furnace approaches as near as may be, to the melting point of the soft or foundery iron—by this means, the harder kinds will be preserved from melting, until they arrive at the state of soft iron. Again, when I wish to produce forge pigs, I increase the quantity of the blast, until the temperature of the furnace rises to the melting point of the hard iron; so that whenever the metal arrives at this state, it melts and passes downward into the hearth, without absorbing any more carbon; while, by the application of so soft a blast, the vitreous matter of the flux is no longer chilled and solidified opposite the tuyères, which so much obstructs the regular working of the furnaces at present.

These improvements I effect by the following means:—

If I wish to produce soft iron with the present blow-pipes, I allow about one-half of the blast, at present in use, to escape; and then withdrawing the blow-pipes so far, as that the expanding stream of air will still fill the openings of the tuyeres, in the same manner as when the full blast was used—or I may reduce the orifices of the blow-pipes to about one-half—say the 3 inch I reduce to 2 or 2½ inch, and then place them in the same position as the former—or I may keep the blow-pipes in their present position; but, in that case, I insert into them a ring or diaphragm, about a foot from their present orifices, so as to diminish their apertures to about one-half. By any of these arrangements, the blast will still be spread over the same surface; or I may still use the same orifices, and the same pressure as is at present in use, and regulate the quantity of blast by the well-known expansibility of the air by heat. Thus, if I wish only about one-half of the air to escape through these orifices with the same pressure, I heat it to about 530°, which will expand it to double its volume. By this means only one-half will escape into the furnace. Again, when I wish to increase the heat of the furnace so as to produce forge pigs, then I lower the temperature of the blast, so that a greater quantity may pass through the blow-pipes—by this means I increase the combustion, and raise the temperature in the furnace. This latter method of increasing or diminishing the blast I prefer, for the following reasons. By supplying the furnace with a blast as rare and attenuated as the air on the summit of the Andes,

where, from the extreme rarity of the atmosphere, wood itself can hardly be made to burn, the combustion will be rendered much more gentle; and, by this means, the fierceness of the heat in the hearth—that focus of combustion in the blast furnace—will be so much subdued and abated, as no longer to injure or oxidize the falling metal in its passage through it; while, by this diminution of the blast, the upper regions of the furnace will be better adapted for cementation, and there will be less risk of melting down the metal before it is sufficiently carbonized, as was the case when the full blast was used; and, from the high temperature of the blast, the flux will not become fixed or solidified as formerly.

In witness whereof, &c.

## THEORY OF THE ELECTROTYPE.

Science never presented society with a discovery that became so immediately popular as the electrotype. No sooner did Spencer and Jacobi intimate to the world, their discovery of multiplying works of art in metals by acting upon their solutions by means of galvanism, than the scientific portion felt as if under the influence of the same subtile power. All felt that they were on the eve of an important change in some of the arts of life, and began to wonder that such a valuable discovery had escaped their notice. Thousands who scarcely ever had given science a passing thought, became fascinated with the new art, and, the process being simple and easy, became excellent electrotypists. It is, therefore, not to be wondered at, that there are many who are expert in all the manipulations of this new and wonderful art, only now putting the question—What are the chemical changes which take place during the process? And how does the battery influence this change? A few words upon this subject may be interesting to many of our readers.

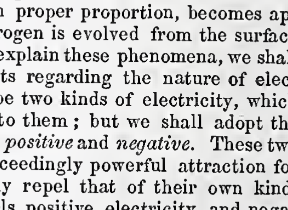
Spencer, in his pamphlet, p. 485, gives the following as the true explanation of electrical deposits:—"If we dip a piece of clean iron into a fluid containing a salt of copper in solution, and let it remain for a few minutes, it will be found to have received a coating of pure copper. If the iron, when first immersed, become *at once thoroughly* coated with the cupreous deposit, and this not dependent on any oxidation on its part, a *solid* but excessively thin metallic coating would be the result, and the piece of iron thus cased would act precisely as a *piece of copper* under similar circumstances, which I need hardly say, would have no further action on the solution. But, such not being the result, let us see what really does take place. No sooner is the iron immersed in the cupreous solution than *oxidation* takes place on portions of *its* surface. This is the primary action; the secondary being the *de-oxidation* of the copper held in solution. This, when set free, at once obeys the laws of elective affinity, and while under *electrical influence* attaches itself to the nearest *metallic* surface. The iron, being only partially oxidized, presents to the copper a surface covered with metallic points; and to these it attaches itself; but the oxidizing process continues *still going forward* in the interstitial spaces that have *not* been covered with copper. But as this proceeds, the prominent points get undermined, and, falling to the bottom, expose fresh surfaces again to be deposited upon so long as there is a piece of *metallic* iron left. The primary action in this, and in most other instances of electro-chemical decomposition, is caused by the decomposition of water, the oxygen of which combines with the iron; the secondary action being induced by the nascent hydrogen which separates the copper in a pure state from the acid, or compound salt radical with which it is in combination. We thus see that iron does precipitate copper in the *metallic* state, and that the phenomenon is electrical."

This explanation of the precipitation of copper from its solutions by iron, is not electrical, further than any other chemical combination is; neither is water decomposed—the whole is simply a case of chemical substitution. The acid that was in union with the copper, having a stronger attraction for iron, leaves the copper and combines with the iron; but the two metals not having sufficient polar attraction to adhere so firm as to exclude the action of the acid, the copper is undermined and falls to the bottom as a powder. After some copper is deposited upon the surface of the iron there is no doubt local galvanic action between it and the iron while they remain in contact; but this is altogether a secondary action, and has nothing to do with Mr Spencer's definition.

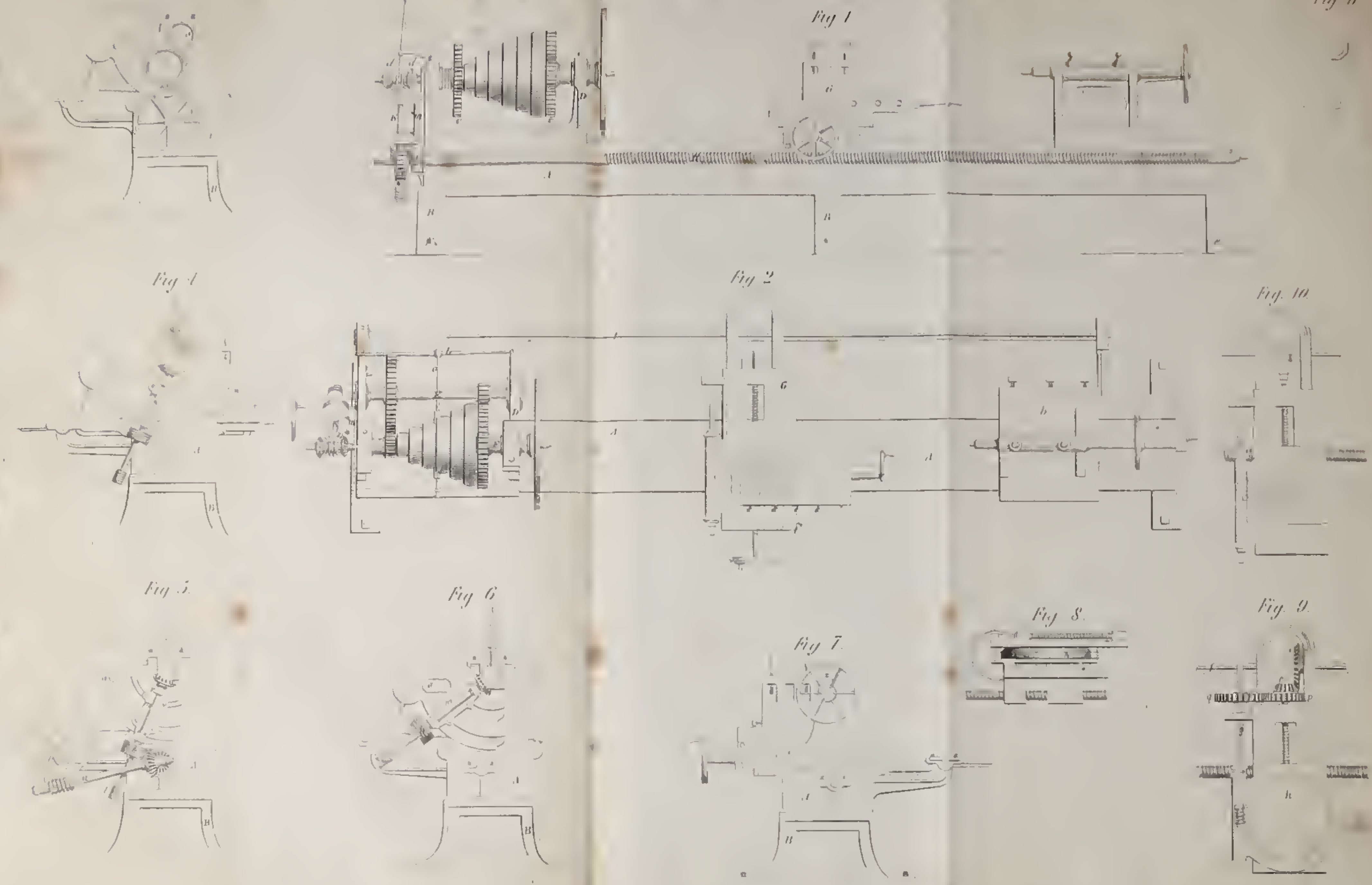
In endeavouring to give a detail of the chemical decompositions which take place during an electrotype process, we shall avoid entering upon the various hypotheses concerning the nature of electricity. Whether it is a distinct substance, or only a property of matter, does not signify for our present purpose. We shall only point out, in course, a few laws which it obeys in reference to the deposition of metals from their solutions, and explain the nature of the changes which take place in these solutions during the reduction of the metal. As a general type of these phenomena, we shall begin with the battery.

If a piece of zinc be immersed into dilute sulphuric acid, a violent action takes place, the zinc is dissolved and hydrogen gas is evolved from its surface, the nature of which action may be explained as follows:—The sulphuric acid is composed of one equivalent of sulphur, and three oxygen, with one water. The water put in to dilute it has no connexion with its composition. It is expressed in symbols thus: $SO_3 + HO$, water being composed of oxygen and hydrogen; but, according to what is termed the new theory, and which we consider the best, and by which we will keep in the following details, the elements of sulphuric acid are arranged thus: one sulphur, four oxygen with one hydrogen, or $SO_4 + H$. The zinc being put into this acid it simply displaces the hydrogen, by what is termed elective affinity; the acid having a stronger attraction for the zinc than for the hydrogen, combines with it and sets the hydrogen free; the sulphate of zinc formed is immediately dissolved by the water which dilutes the acid, so that a new surface of the metal is always being presented to the acid.

If into the same acid we put a piece of copper, there is no further effect produced, the copper remains unacted upon; but if we bring the zinc and copper into contact, even by a wire being attached to each, there is instantly an apparent reversion of action—the zinc, provided the copper be in proper proportion, becomes apparently inactive, and the hydrogen is evolved from the surface of the copper. Before we can explain these phenomena, we shall have to refer to one or two facts regarding the nature of electricity. There is supposed to be two kinds of electricity, which have had many names applied to them; but we shall adopt the first and most common; namely, *positive* and *negative*. These two kinds of electricity have an exceedingly powerful attraction for each other, but they powerfully repel that of their own kind, that is, positive electricity repels positive electricity, and negative repels negative; now all bodies which combine chemically are supposed to do so in virtue of their being in different states of electrical excitement, as for example:—We have already said that sulphuric acid is composed of $SO_4 + H$. This compound atom of sulphur and oxygen is what is termed a salt radical; that is, it acts the part of a simple substance, in uniting with other bodies. Hydrogen being positively electrical, in relation to this salt radical, combines with it when brought under proper circumstances; but zinc being more positively electrical in reference to this salt radical than the hydrogen, they combine in preference, and the hydrogen is set at liberty. When a piece of copper is put into the solution, in contact with the zinc, these metals being highly negative and positive to each other, a polarity is induced, not only in the two metals, but in every particle of acid between the metals; so that we may suppose all the particles of acid arranging themselves with the hydrogen to the copper, and the salt radical to the zinc, as in the annexed diagram. Each of these associated squares represents an atom of sulphuric acid ($SO_4 + H$). The salt radicals of the first atom being in contact with the zinc, its hydrogen *h*, the moment it is set free, combines with the *s* of particle 2, as shown by the brackets, and liberates the hydrogen, which again combines with the *s* of particle 3, and so on through every particle of acid between the two metals, till it reaches the copper, when the last liberated particle of hydrogen, not being in a proper condition for combining with the copper, is evolved from its surface, as gas. We need hardly mention here that it is the electricity, or galvanic fluid, which causes this polarity amongst the particles, and



SCOTT, SINCLAIR & CO'S, SELF-ACTING LATHE,
FOR PLAIN & CIRCULAR TURNING, SCREW-CUTTING & BORING.




Scale Half Inch to a Foot

that electricity passes from the zinc to the copper along with the hydrogen, and proceeds along the wire which connects the metals, and returns again to the zinc. The above constitutes a galvanic battery of a single pair.

Were the wire which connects these two metals broken off at *a*, and each extremity put into a vessel containing a conducting fluid—say water and sulphuric acid—a similar effect is produced, as was in the generating cell or battery, with this difference, that it is not necessary that one end be dissolved and the other not. If the wires be platinum, neither hydrogen nor the salt radical combines with them; the former passes through the liquid in the same manner as already explained; the latter, the moment it is set at liberty, not being capable of combining with that metal, decomposes the first particle of water it comes in contact with, combines with its hydrogen, and forms $S\,O_4 + H$— while the oxygen is set at liberty, and escapes as gas from the surface of the metal. Thus we have the hydrogen of the sulphuric acid escaping at the one pole, and the oxygen of the water at the other. If the wires be copper, the salt radical combines with the copper of that wire, and forms the sulphate of copper, while the hydrogen escapes at the other pole. After the formation of sulphate of copper, there is a double decomposition going on, as both the sulphate of copper and sulphuric acid are decomposed. The salt radical of each combines with the one wire, and both hydrogen and metallic copper pass along to the other, upon which the copper is deposited as a red brown powder—this double action continues till the whole free acid is converted into sulphate of copper. If the fluid in this decomposing cell were a saturated solution of sulphate of copper, ($S\,O_4 + C\,u$,) the salt radical would combine with the positive pole of the battery, while the copper would pass on through the liquid, and deposit upon the negative pole; and, by having this pole in particular shape, or having impressions upon it, a *fac simile* is produced by the deposit, which deposit is termed an electrotype. The above explanation of the electrotype process applies to all electro-metallic depositions, whether copper, silver, or gold; and one law applies to all. 1st, The salt must be in such a state of fluidity as to allow the particles to pass freely amongst each other. 2d, It must be of the nature of a simple compound; that is, composed of two elements, or a salt radical and an element. In our opinion, it is the metallic atom alone which passes from one pole to another, the salt radical acting only as the medium or carrier, as has been already explained, but which may be made a little plainer, if we suppose a number of men sitting together on a form, each having a ball in his hand. Let the man represent the salt radical, (say $S\,O_4$,) and the ball the metal, (say copper;) let a basketful of such balls, placed at the one end of the form, represent a sheet of copper, forming the positive pole of the battery, and another basket empty, at the other end, representing a medal, forming the negative pole. At a given signal, let the man next the full basket lift up a ball, while he hands the one he had to his neighbour, who, as he receives this, hands his to his next neighbour, and so on to the last, who puts his into the empty basket. Let us suppose this continuing, and each man acting simultaneously and with one impulse, and we may have some idea of electrical decomposition, and what is termed the current or passage of the particles from one pole to another. In the above explanation, we have differed considerably from the general method adopted by writers upon this subject; but we have given what we consider to be the most consistent with truth and our own experience, whether it be the most *simple* or not, which appears to be the reason for giving a different explanation by an eminent chemist of the present day.* "The simplest mode of accounting for these phenomena," says he, "*is to say*, that water is decomposed, because the oxygen is attracted more powerfully by the positive pole of the galvanic battery than by the hydrogen, with which it had previously been associated, whilst this last is more powerfully attracted by the negative pole than by the oxygen. The elementary bodies separate, therefore, from each other, but not being capable of entering into combination with the substance of the poles, they are evolved."

This is the general explanation given; but, we believe, more from a tenacity to old opinion than simplicity—the necessity of acidulating the water being referred to *disposing* affinity,—a convenient term, signifying, "not properly understood."

* Dr. Kane's Elements of Chemistry.

## WHITWORTH'S PATENT SELF-ACTING LATHES.

*(Illustrated by Plate.)*

*Small Lathe.*—The three views of the lathe given in the annexed plate, show all its peculiarities. Of these views fig. 1 is a side, and fig. 2 an end elevation. Fig. 3 is a section showing the upper part of the compound slide placed at right angles to its position in fig 1. The same letters refer to the same parts in all the figures.

A A, lathe-bed. It is of cast-iron, and has the upper surfaces of its flanches *a a*, planed true. It will also be observed (fig. 3) that one of the flanches is broader than the other: it thus affords cover and protection to the leading screw D, and brings it nearer the centre line of traction. The bed is fixed upon cast-iron standards.

B B, fast headstock. It is held in its position upon the lathe-bed by strong bolts, and carries the case-hardened mandril *b*, in collars of hardened steel. Upon the mandril are placed the driving-cone *c* (loose), the spur-wheel *d* (fast), and a small pinion, which gears into the spur-wheel *d'*. This pinion is shown in fig. 1, but has no letter upon it: it is attached to the end of the cone, and is, consequently loose upon the mandril *b*. The wheel *d'*, is fixed upon the spindle *e* (seen in fig. 2); and upon the other end of the same spindle, and fast, is a pinion which gears with the wheel *d*. These wheels and pinions being all in gear, a reduced motion is communicated to the mandril *b*; but the wheel *d'*, and the pinion upon the same spindle *e*, being thrown out of gear, and the cone *c* being made fast to the wheel *d*, the mandril *b* has the same speed as the cone receives. In fig. 1 the mandril is shown with Clement's equilibrium driven upon it; but any other form of chuck may be used.

C C, shifting headstock. The under surfaces are planed true to adjust it to the planed surfaces of the lathe-bed flanches. It is held in its position by a bolt and washer, in the ordinary mode. Its spindle is adjusted by a screw worked by the wheel *f*; and is held fast by a pinching screw, worked by the small handle *g*.

D, leading screw for communicating motion to the compound slide E. It is driven by a train of wheels communicating with the spindle *b*. It passes through, and forms the axis of a moveable piece *h*, and, at its extremity, carries the fast wheel *i*, which gears into a pinion *k*. This, and the wheel *l*, which gears into the pinion *m*, upon the end of the mandril *b*, are carried by a stud *n*, fixed in a straight slot of the moveable piece *h*. This moveable piece has, likewise, a circular slot near the end of it, through which two fixed studs pass. Upon the ends of these studs pinching-nuts *h' h'*, are placed; and these, being screwed tightly up, hold it in its place. By altering the angular position of this moveable piece *h*, a pinion of greater or less diameter than *m* may be placed upon the end of the mandril *b*; and thus the motion of the leading screw is regulated.

E, compound slide. *o o* is the under slide. It communicates with the leading screw by means of a nut formed of two jaws, which are opened and closed at pleasure, by a lever *p*, fixed on the axis of a wheel containing eccentric curves. This axis, and those of the jaws, have their bearings in solid pieces cast on the bottom slide *o o*, and projecting downwards between the flanches of the bed A A. *q* is the under bed which carries the top slide *r*. It has two flanches, *q'*, formed on its under part, exactly opposite to each other—one extending in front of the piece *q*, and the other extending beyond on the corresponding face behind; and in these flanches are cut circular slots, each equal to an arc of ninety degrees. These slots receive two dovetail bolts, which are screwed above the flanches, and have pinching nuts fitted on them to hold the bed *q* in the angular position in which it is placed upon its rest *o o*. This angular position may be changed at pleasure, by slacking the nuts; and may be moved at right angles to the bed of the lathe, by means of the dovetail heads of the bolts which shift in a dovetail groove in the bed *o o*. The part *q* carries the slide *r*, which is shifted by the screw *s*. Upon this again rests the top slide *t*: this carries the cutting tool, and is adjusted upon its rest by the screw *u*. *v v* are screws for fastening the tool to the slide.

In fig. 3, which shows the top slide adjusted for turning face-work, *w* is a screw wheel put in motion by the leading screw D.

When the nut communicating with the leading screw is open,

this wheel allows the slide to be shifted by hand; for by turning the handle $x$, motion is communicated to it by means of the bevil wheels seen in a recess of the upper part of the compound slide, and it thus works upon the leading screw exactly as a pinion in a rack. The axis of the screw wheel passes perpendicularly through the bottom of the slide $o\ o$. In surfaceing, the bottom slide being firmly fixed to the bed by means of the tightning screw $y$, provided for that purpose, and the guide screw being in revolution, a rotary motion is given to the screw-wheel, which by the bevil wheel upon the upper end of its axis is communicated to a shaft passing across the bottom slide, and carrying a spur wheel $z$. This last gears with another spur wheel $z'$ upon the end of the screw $s$ in the top rest to which it gives motion. In this arrangement, the handle shown in fig. 1 is removed from the end of the screw $s$. All the wheels have the same size of socket, and can thus replace each other in any order required.

From the arrangement described, it will be seen that the compound slide is self-acting, or may be moved by hand as occasion requires; and is adapted for turning cones, surfacing, sliding, or screw-cutting.

*Large Lathe.*—The cast-iron base plate A A extends throughout the whole length of the lathe, and is intended to be bolted down on a stone foundation. The upper surface is planed true, and is intersected by mortices, B B B, for holding down the bed, C C, and rest slide, D, in any required position, and for fixing large cylinders when the lathe is used for boring. A solid standard, E E, for holding the fast headstock, F F, is cast on the base plate, A A. The shifting headstock, G, is placed on the bed, C C, and is moveable on the base plate by a rack, H, and pinion (not shown). The bed, C C, is secured in its true position by guide pieces cast upon it, and planed to fit into grooves of the base plate. These grooves allow it to be moved close up to the fast headstock, or drawn out to form a pit of the extent that the size of the base plate will admit; in all the positions of the bed the lathe is self-acting. A horizontal shaft, I I, running under the base plate is driven by an upright shaft, K, which communicates with the spindle of the fast headstock. The bevil wheel, L, on the upright, K, gears with two pinions, loose upon the horizontal shaft, which may thus be connected with either by a sliding clutch in the ordinary mode, and consequently driven in either direction as occasion requires. The motion thus obtained is communicated to a second horizontal shaft M, which runs parallel with the former in bearings above the base plate, by spur-wheels at the extremity. The change-wheels N of the leading screw O are driven from it by a sliding pinion P, upon the upper shaft, and may thus be connected in any position of the bed. Sliding pulleys on the same shaft may be used to give self-acting motion to the cylinder of the shifting headstock.

When the surfacing motion is used, the top rest is placed across the bottom, as shown in fig. 3, of the small lathe; and in turning large cylinders, the top rest is transferred from the bottom slide to the standard D, which is bolted on the base plate. On the back of the face-plate is an internal wheel Q, within which a pinion works when the back-speed is used.

All the other parts of the lathe, the form of the bed, the position of the leading screw, and the arrangement of the parts of the compound slide, are the same as in the small lathe.

## ON THE CHANGE-WHEELS TO BE USED IN SCREW-CUTTING.

Suppose the leading screw to be cut to two threads in the inch, the following table shows the train of wheels to be used in cutting screws of different degrees of fineness, from 1 thread to 70 in the inch. In the first columns, it will be observed, that the wheel and pinion, carried by the stud $n$, are omitted—these not being required in cutting screws of the pitches there stated, are displaced, and a simple carrier wheel is substituted for them. To facilitate this arrangement the wheel $i$, on the leading screw, has the pap of its socket longer on one side than the other; so that, when reversed, as in this case, it is brought into train with the carrier wheel, placed upon the stud; and this, again, is placed in train with the pinion $m$.

| No. of threads in inch of screw. | No. of teeth on | | No. of threads in inch of screw. | No. of teeth on | | | | No. of threads in inch of screw. | No. of teeth on | | | | No. of threads in inch of screw. | No. of teeth on | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mandril pinion *m.* | Leading-screw wheel *i.* | | Mandril pinion *m.* | Stud-wheel *l.* | Stud-pinion *k.* | Leading-screw wheel *i.* | | Mandril pinion *m.* | Stud-wheel *l.* | Stud-pinion *k.* | Leading-screw wheel *i.* | | Mandril pinion *m.* | Stud-wheel *l.* | Stud-pinion *k.* | Leading-screw wheel *i.* |
| 1 | 80 | 40 | 8¼ | 40 | 55 | 20 | 60 | 18 | 40 | 60 | 20 | 120 | 32 | 30 | 80 | 20 | 120 |
| 1¼ | 80 | 50 | 8½ | 90 | 85 | 20 | 90 | 18¾ | 80 | 100 | 20 | 150 | 33 | 40 | 110 | 20 | 120 |
| 1½ | 80 | 60 | 8¾ | 60 | 70 | 20 | 75 | 19 | 50 | 95 | 20 | 100 | 34 | 30 | 85 | 20 | 120 |
| 1¾ | 80 | 70 | 9½ | 90 | 90 | 20 | 95 | 19½ | 80 | 120 | 20 | 130 | 35 | 60 | 140 | 20 | 150 |
| 2 | 90 | 90 | 9¾ | 40 | 60 | 20 | 65 | 20 | 60 | 100 | 20 | 120 | 36 | 30 | 90 | 20 | 120 |
| 2¼ | 80 | 90 | 10 | 60 | 75 | 20 | 80 | 20¼ | 40 | 90 | 20 | 90 | 38 | 30 | 95 | 20 | 120 |
| 2½ | 80 | 100 | 10½ | 50 | 70 | 20 | 75 | 21 | 80 | 120 | 20 | 140 | 39 | 40 | 120 | 20 | 130 |
| 2¾ | 80 | 110 | 11 | 60 | 55 | 20 | 120 | 22 | 60 | 110 | 20 | 120 | 40 | 30 | 100 | 20 | 120 |
| 3 | 80 | 120 | 12 | 90 | 90 | 20 | 120 | 22½ | 80 | 120 | 20 | 150 | 42 | 50 | 140 | 20 | 150 |
| 3¼ | 80 | 130 | 12¾ | 60 | 85 | 20 | 90 | 22¾ | 80 | 130 | 20 | 140 | 44 | 30 | 110 | 20 | 120 |
| 3½ | 80 | 140 | 13 | 90 | 90 | 20 | 130 | 23¾ | 40 | 95 | 20 | 100 | 45 | 30 | 90 | 20 | 150 |
| 3¾ | 80 | 150 | 13½ | 60 | 90 | 20 | 90 | 24 | 65 | 120 | 20 | 130 | 45½ | 40 | 130 | 20 | 140 |
| 4 | 40 | 80 | 13¾ | 80 | 100 | 20 | 110 | 25 | 60 | 100 | 20 | 150 | 50 | 30 | 100 | 20 | 150 |
| 4¼ | 40 | 85 | 14 | 90 | 90 | 20 | 140 | 25½ | 30 | 85 | 20 | 90 | 52 | 35 | 130 | 20 | 140 |
| 4½ | 40 | 90 | 14¼ | 60 | 90 | 20 | 95 | 26 | 70 | 130 | 20 | 140 | 52½ | 40 | 140 | 20 | 150 |
| 4¾ | 40 | 95 | 15 | 90 | 90 | 20 | 150 | 27 | 40 | 90 | 20 | 120 | 55 | 30 | 110 | 20 | 150 |
| 5 | 40 | 100 | 16 | 60 | 80 | 20 | 120 | 27½ | 40 | 100 | 20 | 110 | 56 | 30 | 120 | 20 | 140 |
| 5½ | 40 | 110 | 16¼ | 80 | 100 | 20 | 130 | 28 | 75 | 140 | 20 | 150 | 60 | 30 | 120 | 20 | 150 |
| 6 | 40 | 120 | 16½ | 80 | 110 | 20 | 120 | 28½ | 30 | 90 | 20 | 95 | 65 | 30 | 130 | 20 | 150 |
| 6½ | 40 | 130 | 17 | 45 | 85 | 20 | 90 | 30 | 70 | 140 | 20 | 150 | 70 | 30 | 140 | 20 | 150 |
| 7 | 40 | 140 | 17½ | 80 | 100 | 20 | 140 | | | | | | | | | | |
| 7½ | 40 | 150 | | | | | | | | | | | | | | | |
| 8 | 30 | 120 | | | | | | | | | | | | | | | |

This table may still be employed when the leading screw has four threads to the inch; for the same train of wheels will suit in cutting screws of double fineness. And, similarly, when the leading screw has only one thread to the inch, a screw of only one-half the fineness will be produced with any train found in the table.

# M. CARON'S PATENT WATER EXTRACTOR.

This machine is intended for the extraction of water from silk, cotton, and woollen cloth, and yarn, and is exceedingly valuable for printed goods in which the colours are liable to mark off in the ordinary way of pressing the water out of the goods. There is besides not the slightest danger of cutting either cloth or yarn that may be put into it. The arrangement and mode of action will readily be understood by reference to the drawings, of whieh fig. 1 is a front elevation, fig. 2 is an end elevation, but showing in section the copper vessel for containing the cloth or yarn. The same letters of reference denote the same parts in both the drawings.

A A are the two side frames of the machine, which are connected together by three stays, B B B. C, outer side frame for supporting the ends of the shafts that carry the pulleys and wheels for communicating motion to the machine. D D, outer case or cylinder for collecting the water that is thrown out of the revolving cylinder E E. F, tube or pipe for conveying away the water. G, under bridge for carrying the outer cylinder, in the centre of which is a bush for steadying the upright spindle H. Encircling the bush is a cup for containing oil to keep the spindle H cool. I, top bearing for keeping the spindle from vibrating, by reason of the great velocity with which it revolves. J, bearing of shaft K. L, two bevil wheels for connecting the spindle H and the shaft K. The wheel upon the upright spindle is placed with the teeth upwards, so that the pressure of the two wheels working may tend to keep the spindle securely in its place. *n n n*, three spur wheels keyed upon the shaft K, and driven by the three corresponding wheels upon the shaft N; the small wheel 2, and the pulley 3, alone being fast upon the shaft N, all the others running loose. The wheel 4, and pulley 5, are connected by a hollow bush which is loose upon the shaft N. On the outside of this bush runs another tube or bush, on

*Fig.* 1.

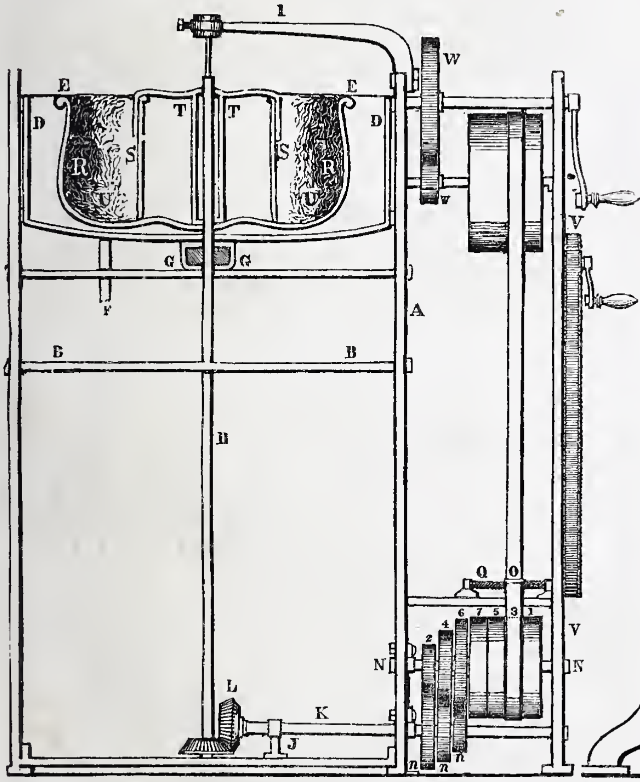
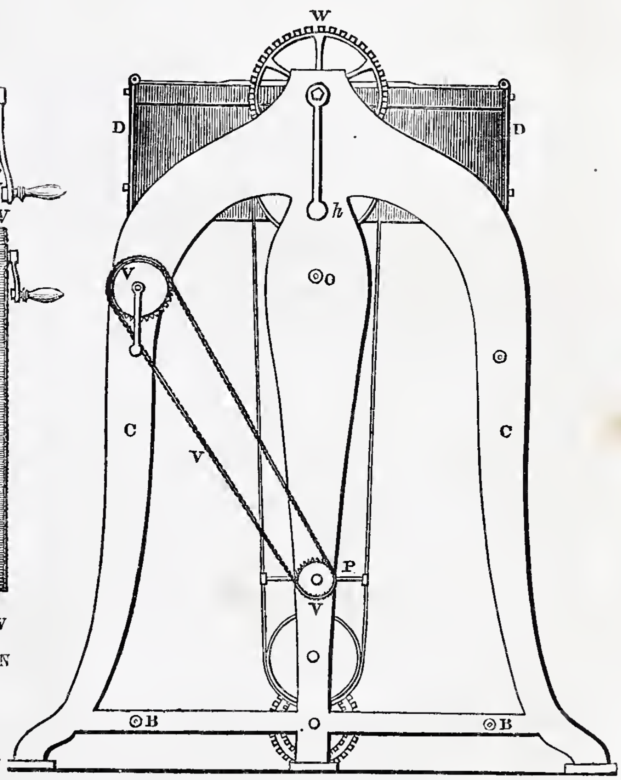


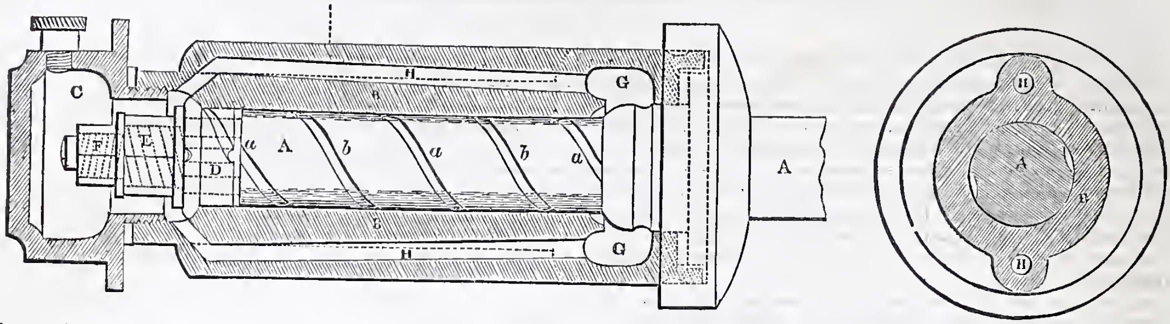
*Fig.* 2.



which are fastened the wheel 6, and pulley 7. 1 is a loose pulley for the belt to run upon when the machine is not at work. O, traveller or guide for shifting the belt from one pulley to an other by means of the fork P. Q, screw passing through the traveller, and wrought by the endless chain and pulleys, V V V, seen in the end elevation, fig. 2. The section of copper cylinder into which the cloth or yarn is put, fig. 1 shows the form and arrangement of the different parts. The outside case, E E, is pierced with holes $\frac{1}{10}$th of an inch in diameter, and one inch apart. S S, inner case into which is fastened the brass tube T T, through which a groove is cut, the entire length of the tube, for fitting on to a tongue or feather on the upright spindle H. U, space between the two cylinders, into which the cloth or yarn is put from which the water is to be extracted.

The mode of working the machine is as follows:—The cylindrical space is to be filled with the cloth or yarn, care being taken that the machine is equally filled all round, as from neglect of this the machine will work very unsteady, besides having a tendency to bend or break the spindle. The cylinder being filled, the driving belt is to be gradually moved on to the first pulley, and left there till the running of the water nearly ceases at the tube F, the belt is then shifted on to the next pulley, and so on till it is on the last pulley, when the machine should make 1500 revolutions per minute—that is, in a machino of 40 inches diameter, whieh will contain about 16 pieces of cotton cloth, the time required for the operation, from 8 to 10 minutes.

## BROWNLIE'S IMPROVED CARRIAGE AXLE.




This axle has undergone the test of long and varied experience; and it has proved much superior to others. If properly supplied with oil at first, it will run for three months together, before it requires to be again oiled.

A is the axle; B, the bush, which is ground on the axle; C is the oil-box, screwed to the bush, with leather packing between them; D is a broad ring, of the same outside diameter as the axle, and fitted on the end of it, which has two opposite flat sides filed on it, to prevent the slipping of the ring. The ring has a semicircular shoulder, by which it bears against the bush; and it is screwed up against it by the nut E; thus the bush is retained on the axle between the shoulder on the ring, and that on the axle at the other extremity. The nut, E, turns on a right-handed screwed part of the axle; and F is a jam-nut, turning on a left-handed screw of a finer pitch. On the surface of the axle are cut two spiral grooves, *a* and *b*, which are continued on the surface of the ring D, and terminate on its shoulder. G is a cavity turned in the bush, and H H are two channels running within the feathers cast on the outside of the bush, for the usual purpose of retaining it in the nave of the wheel. These channels connect the cavity, G, and the oil-box C.

When the axle is to be put in action, the box, C, is filled with oil by the pin hole. Now the bush, turning with the wheel to which it is fixed, and the oil box along with it, the rotatory motion is communicated to the oil within, which thereby enters the spiral channels; and the continued motion of the bush will urge it along the spiral into the cavity, C, whence it returns by the channels, H H, into the box, C. Thus a constant circulation of the oil is induced, and the axle is properly lubricated.

## PORTABLE COMB-CUTTING MACHINES.

*Fig.* 1.

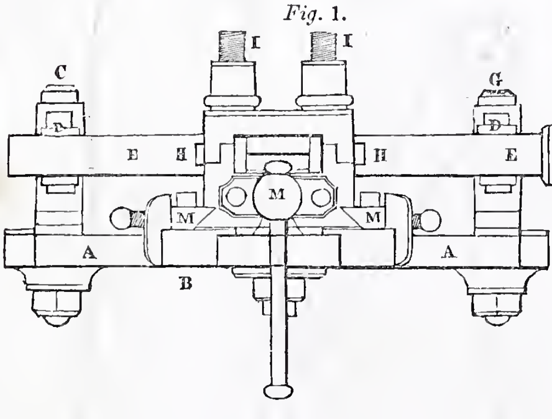



*Fig.* 2.

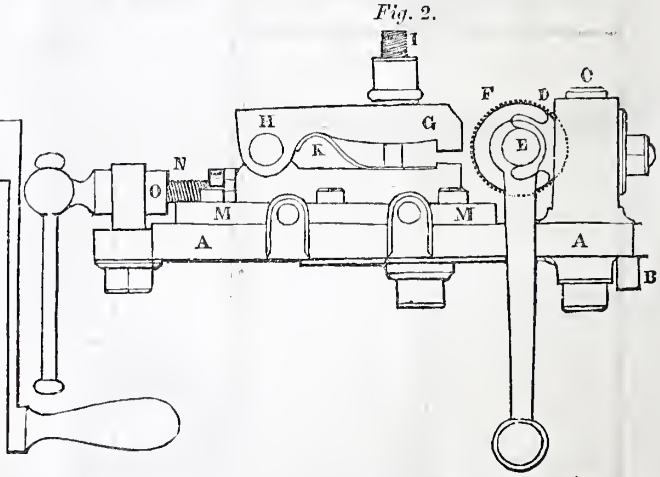



Fig. 1 is a front view of the machine; fig. 2 is a side view. A A is the sole-plate of the machine, with a projection, B, cast on its under side, by which it may be held firmly in a vice when in use. To this plate are fixed two standards, C C, with vertical grooves in them, by which the bushes, D D, sliding in them, are adjusted to the level required, and then fixed by screw nuts behind. These bushes, being half round, are open in front, so as to facilitate the removal and replacing of the spindle E E, which runs in them. This spindle is truly cylindrical, and without ruffs, except in the middle, and thus it is free to move lengthways in the bushes. On the middle, which is of a larger diameter, the cutting barrel, F, is fixed by a key seated on the spindle, and by a nut screwing it tight against a ruff. The barrel is of the usual construction, the threads being cut into rows of teeth parallel to the axis, and both sides of the teeth thus presenting cutting surfaces. G H H is the vice for holding the comb intended to be cut. The upper jaw is hinged to the under at H H; they are screwed together by the bolts and nuts I I, the bolts being tapped into the lower jaw. In fig. 2, the vice is shown open to receive the comb. Two springs, K, keep it in this position when the screws I I are relaxed. The bolt, L, screws into the under jaw, for steadying it, and works along a groove in the sole, against which it bears with a ruff. The under jaw also works longitudinally between a pair of parallel slides, M M, bolted to the sole, and is moved in them by the screw N, which works into a nut O, bolted to the front end.

When the machine is to be used, the intended comb is introduced into the vice, and fixed there by the screws I I, as in fig. 2. The barrel is then set to the level suited to give the required bevel to the teeth of the comb; and the comb is pressed forward against it by the action of the screw N. By driving the handle, the teeth cut into the comb, and thus the spindle moves lengthways in its bushes, till it clears the comb on one side. By pressing this forward again, and reversing the motion of the handle, the barrel retraces its path, and arrives at its first position. The repetition of this process is necessary till the comb be completed. In this way, as the cutter acts both ways, no time is lost.

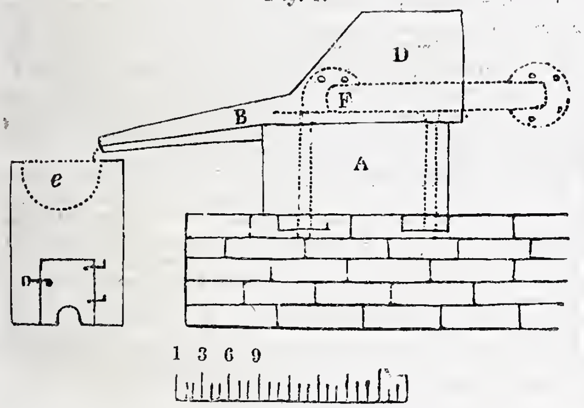
## ON THE USE OF HOT BLAST IN THE SMELTING OF LEAD.

*(From Silliman's American Journal.)*

The reduction of lead ore is effected in a great variety of furnaces, many of them primitive and simple; others requiring great expense in erection, and much practical experience in the management. Yet these latter often give no better results than the original "log furnaces" of our western pioneers. The great saving of labour and certainty of product effected by the furnace described below, induces the preparation of this article for publication. Should the writer be able to repay thereby a moiety of debt which is constantly accruing against him by the scientific labours of others, as published in your Journal, he will be much gratified.

To reduce the sulphuret of lead, merely requires that the sulphur should be disposed of by combustion; hence a process so simple is *partially* effected by the most simple means. Yet it can only continue successful, when the heat is not so high as to fuse the galena, and when all parts of the ore undergoing the process, are well supplied with atmospheric air to effect this combustion. If the blast be heated and made to diffuse itself equally through the whole "charge," carrying with it the flame of light fuel, pine, or other light wood, leaving but little coal, the reduction of the ore is effected with an economy and despatch hitherto unknown in the processes of reducing this metal. The following is a description of the hot-blast furnace used at Rossie, in the state of New York. The form of the furnace is not new.

*Fig. 1.*

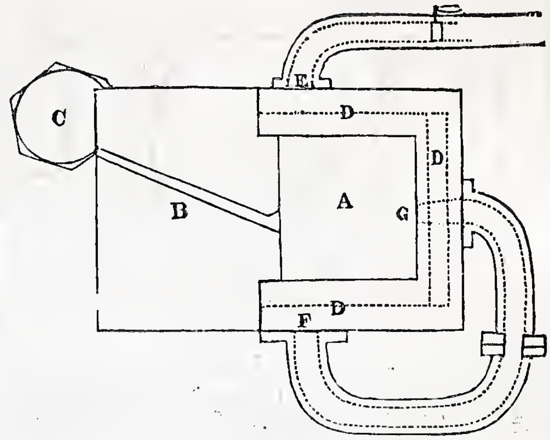



Scale of inches.

A, (fig. 1,) is a cast-iron reservoir, twenty-four inches square, and twelve inches deep, the iron of the sides and bottom is two inches thick; to this is attached the hearth, B, with flanges projecting at the sides, the whole twenty-two inches in length, and, including the flanges, thirty-two inches wide. The hearth descends about one inch in twelve, and has a groove for the molten lead to discharge into the reservoir, C, in which it is kept fused by a small fire under it. D, is a cast-iron air-chest, making an iron wall fourteen inches high, above the sides of the reservoir. It is six inches thick outside; the iron being about three-fourths of an inch thick, leaves the inside space about four and a half inches by twelve and a half. The blast passes into this chest by a pipe at E, and out at F, whence, by a curved pipe, it is discharged into the fire through a "twyer" cast in the air-chest at G, two inches above the level of the lead reservoir.

The lead reservoir, A, (fig. 2,) is filled with metallic lead, which, in the process of smelting, continues in a state of fusion, and while the furnace is used is not withdrawn. The "charge" in the process of smelting, floats upon the molten lead, and the metal as smelted falls into it, flows over, and discharges through the groove in the hearth. In working the furnace, the smelter throws immediately in front of the blast, two or three billets of light wood—say two inches in diameter and sixteen inches long—upon which are thrown up the "charge" in process, and fresh galena, filling the furnace nearly even with the top of the air-chest, and sloping down to the hearth. The blast being let on, strikes upon the billets of wood, and is thus diffused evenly through the whole charge, carrying with it the flame of the fuel.

*Fig. 2.*




It will be perceived that the air, passing into the hollow chest, acts as a refrigerator upon the inner walls, and thereby prevents their being heated so high as to combine with the sulphur, by which they would soon be destroyed; and also, by preventing an accumulation of heat in the walls, keeps the furnace of a uniform temperature, which, if not thus moderated, would soon run so high as to fuse the galena, and thus check the smelting.

The air, by thus passing through the hollow chest, becomes heated, and being thrown in this state through the mass of burning sulphuret, reduces it, in a great measure, by the combustion of its own fuel, the sulphur; the quantity of wood consumed being less than one-fourth of a cord for the product of 2000 lbs. pig lead. The fuel used is wood only, and that of the lightest kind; coal, or other *concentrated* fuel, gives a heat too intense near the blast, and reduces the product in a given time, from one-third to one-half.

In operating the furnace, it is necessary to charge it about once in ten minutes, which is done by drawing the "charge" forward upon the hearth, (the blast having been previously shut off by a valve, to protect the smelters,) billets of wood are thrown in, in front of the "twyer," and the charge thrown back with the requisite quantity of fresh mineral, when the blast is again let on. The furnaces continue to run thus, without intermission, night and day, for six days in the week.

The economy and efficiency of this furnace will be understood from the following facts:—In smelting about 5,000,000 lbs. of lead at the Rossie smelting works, the average product at each furnace was about 7,500 lbs. for each day of twenty-four hours. Number of men employed, two at a time, four in all at each furnace. Amount of wood consumed, three-fourths of a cord per day. The cost of *mere smelting*, not reckoning use of works, cost of creating blast, or superintendence, was as follows:—

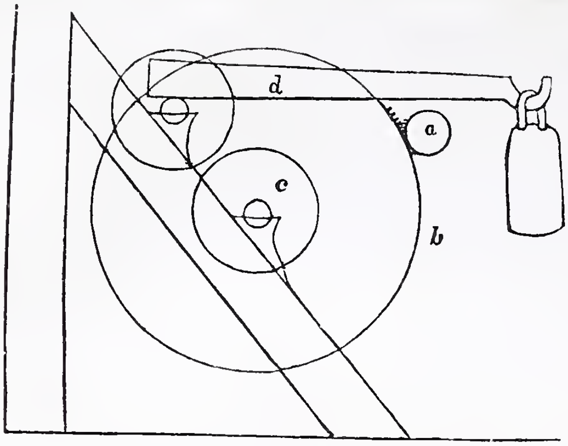
| | Dollars. |
|---|---|
| Two smelters at 1,50 dollars per day, . . . | 3,00 |
| Two assistant do. 1,00 " " . . . | 2,00 |
| Three-fourths cord prepared wood, at 2,00, . . | 1,50 |
| | 6,50 |

for a product of 7,500 lbs., or about 1,75 dollars per ton.

*Preparation of the ore.*—Where saving of labour is so great an object as it is in this country, it may not be uninteresting to describe the method and machinery used for preparing the ore at Rossie. The smelting works are situated at a water power upon Indian River, at a convenient distance from the mines. The ore in the mines lies in a matrix of calc spar, through which it is scattered in crystals of all sizes and proportions, from galena, with a small per cent. of gangue, to gangue with a very small per cent. of galena, so that a large proportion of the diggings requires to be crushed and washed in order to procure the whole product of the mines.

Fig. 3 is a crusher of cast-iron. Into this the ore and gangue are thrown, and reduced, so that none of it is larger than half inch cubes, and as little of it crushed very fine as possible.

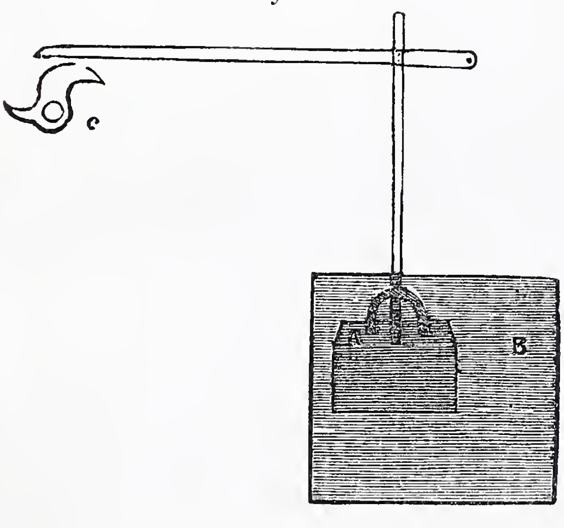
*Fig.* 3.




*Single Crusher used at Rossie.*—*a*, driving pinion. *b*, wheel attached to lower crusher, *c*. *d*, upper crusher, filled with lead, and weighed down by lever, *d*. Whole pressure of the crusher—say 4000 lbs.

Fig. 4 is a bucket sieve; A, a square box with iron bottom, perforated with small holes, suspended in the vat of water, B, in which it is agitated by cam O. The diggings from the crusher being thrown into this sieve, and the lever let into the cam, the contents of the sieve immediately arrange themselves in strata according to their relative gravities; first, clean gangue on the surface; next, "middlings," being spar with particles of ore attached, (these are thrown back to be recrushed;) next, lead ore,

*Fig.* 4.




the surface of which has more or less gangue adhering, the lower strata nearly pure. The ore, as smelted, contains from five to ten per cent. of calc spar adhering and scattered through it. The mineral which passes through the sieve is taken from the vat and washed in a stream of water upon an inclined table, both so graduated that the ore remains near the stream and the impurities may be carried off.

*The Rossie Lead Mines.*—Of the bubbles of '36 and '37, perhaps none was more *unmercifully* inflated than that of the Rossie lead stock. It is unfortunate for the mining interest in that very interesting and promising region, that this remarkable mine should have become, by a ten years' lease, the property of a company, and thus made at once the victim of speculation. In taking out the ore for the first one hundred feet in depth, little expense was necessary, and the product and profits were large. At the depth now attained—say from one hundred and seventy-five to two hundred feet—permanent and adequate machinery and good engineering are required, having reference to working the mine for a long series of years. The investments necessary for this can hardly be looked for, until the fee of the land, and the rights to the mine, are owned by the same person or company. The amount of lead smelted from these mines in 1837 and 1838, was 4,137,871 lbs.; in 1839, about 1,200,000 lbs.; in 1840, about 400,000 lbs.

The primitive rock, (hornblende gneiss,) in which this mine lies, has but few fissures through which water is discharged, and hence is easily kept free. It is already wrought one hundred feet below Indian River, which flows some eighty rods distant. Whatever may be the difficulties of the present unfortunate tenure of this valuable mine, there is little doubt that it will eventually be efficiently wrought, and yield a uniform and adequate return. The vein descends perpendicularly; the quantity of ore in a given space holds about the same, and in all probability is inexhaustible.

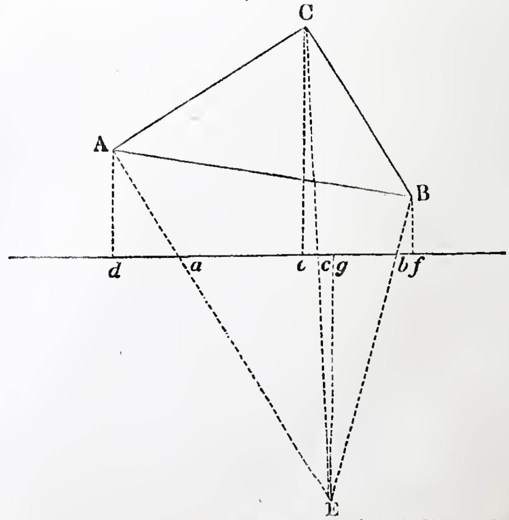
## LINEAR PERSPECTIVE.

### CHAPTER III.

1. It will be seen by reference to the last article on perspective, that in the three cases of the square which were taken into consideration, in which the plane of the picture was parallel to two of its sides; that these sides were parallel to one another in the representation, and the other two sides converged to the point of sight; but in (5) where the sides were oblique to the plane of the picture, it was seen, that in the representation, the two sides, which in the former cases were parallel, are no longer so, but converge to a point on the horizontal line, whilst the other two converge to another point also on the horizontal line. This will take place if they be accurately constructed; whereas, those lines which circumscribe the square, converge to the point of sight, or are parallel to one another, as the case may be. These points to which the lines converge, are called *vanishing points*, and are in general on the horizon.

2. Linear perspective is of two kinds. The first is called *direct* or *parallel*; it is the same as described in Chapter II. This is the easier sort: it is so called, because, in the face of the object (which is parallel to the plane of the picture,) in the representation the horizontal lines are parallel, whilst on the end or flank, these lines converge to the point of sight. The second kind is called *indirect*, because those lines which in the former case were parallel to one another and to the horizon, in this are not, but converge to the vanishing point; and also those on the end or flank, which in the former case converged to the point of sight, in this they converge to a vanishing point.

*Fig.* 1.




As the two kinds are differently managed, and *direct* being the easier, we shall consider it first:—

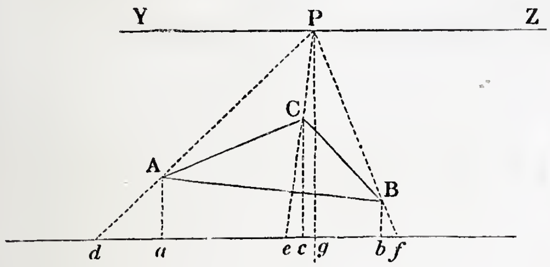
3. By proceeding nearly in the same manner as that adopted in (5), we could, by direct perspective, put the plan of any object into this sort of it when the figure is bounded by right lines; and as will subsequently be seen, the plan of any figure, no matter by what sort of lines bounded. Now, that we be perfectly understood in this, we will put first a triangle, and then any rectilineal figure by this method into perspective.

4. To put a triangle into perspective by the direct method.

Let A B C, fig. 1, be the triangle, *d f* the section line, E the point of view. Draw the visual rays E A, E C, E B, cutting the section line in *a c b;* draw also the perpendiculars A *d*, B *f*, C *e*, and the principal visual ray E *g*.

In fig. 2, draw the base line *d f*, at the proper height, also the horizontal line Y Z. Let *g* P represent the principal visual ray, proceeding to the point of sight P; leave off *g d*, *g a*, &c., equal to *g d*, *g a*, &c. Draw lines to the point of sight P, from *d*, *e*, *f*, and raise perpendiculars from *a*, *b*, *c*, to meet these

*Fig. 2.*

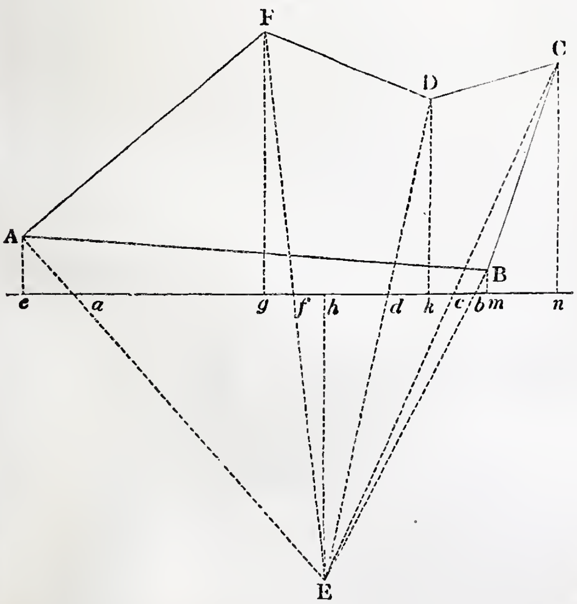



lines respectively, and they will mark out the points A, B, C, which being joined, give the required representation.

5. To put any rectilineal figure into perspective by the direct method.

Since any rectilineal figure is composed of triangles connected with one another, it follows, that the figure can be easily put into perspective when the method of putting the triangle is known.

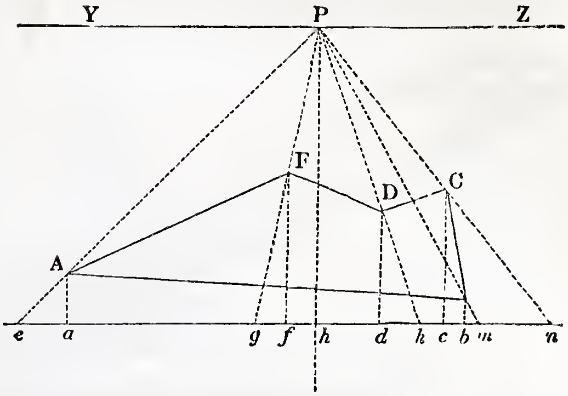
*Fig. 3.*




Let A B C D F, fig. 3, be the rectilineal figure, *e n* the section line, E the point of view; draw the visual rays E A, E F, &c., and the perpendiculars A *e*, F *g*, &c.

Then in fig. 4, draw the base line *e n*, the horizontal line Y Z,

*Fig. 4.*




and take the point of sight P, and let P *h* be the principal visual ray. Leave off *h e*, *h a*, &c., respectively, equal to *h e*, *h a*, in fig. 3, and draw the lines *e* P, *g* P, *k* P, *m* P, *n* P, to the point of sight, and from the points *a*, *f*, &c., draw perpendiculars until they respectively meet the other lines in the points A, F, &c.; these points being joined will give the representation.

6. Having now shown the method of putting the plan of any object, when bounded by right lines, into this perspective; before proceeding to the consideration of objects with regard to height, we would recommend the reader who may read this, and who would wish to become acquainted with this useful branch of science, to make all the figures two or three times the size here shown, and afterwards progressively introduce others which the fancy may dictate—such as quadrilaterals, pentagons, hexagons, &c.—as a short practice will sooner and more efficiently bring it home to the mind than any descriptions, no matter how well and how easily written.

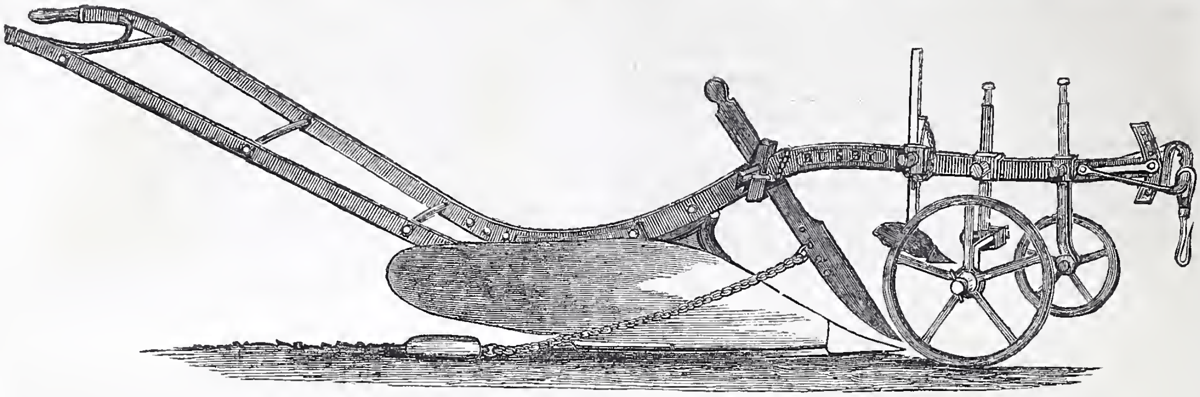
We are well aware from a very particular examination of the principles of direct perspective contained in various works, such as Ferguson's, Hayter's and a voluminous work by a French Jesuit, translated by Chambers, &c. &c., that the way we treat it is different from theirs a little; yet ours is conducted in the same manner as that adopted in indirect perspective—with this difference, that in the latter there are vanishing points to which the lines converge, whereas it is to the point of sight they converge in the former, as described by writers on this branch; and it is our opinion, that it is founded upon rational principles, and deducible from mathematical precedents, and easy in its application.

7. With respect to the distance the observer should stand from the object, some lay it down as a rule to stand off, the distance of the two visible sides taken together—as, if the object were a house, to stand off a distance equal to the length of the two sides which are seen; whilst others consider this too little, and we think it answers better to stand farther off than this—say about as much, and one-fourth or one-third as much more. It greatly depends on taste; but there are some positions which give better perspectives than others, as is very soon learned from practice. Others stand off such a distance as the angle comprehended between the extreme visual rays which proceed to the object, may be about 60° as the angle A E B, in fig. 2 of Chapter II.

## BUSBY'S EXHIBITION PRIZE PLOUGH.

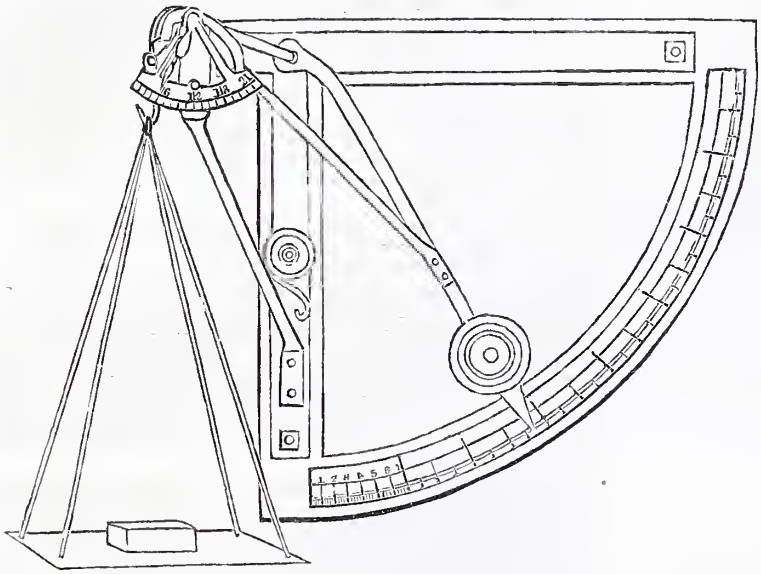
This plough (Class IX., No. 15) was pronounced to be the best which appeared at the Great Exhibition, and a large medal was awarded to the inventor, Mr. Busby, of Newton-le-Willows, near Bedale, Yorkshire. Its distinguishing feature is in the scientific form and great length of the mould-board, which is said to turn the seam better, and with a lighter draught, than any other form of plough yet discovered. Another important peculiarity is the moveable nose-piece,

on which the share is placed, and which has the great advantage that, where cast-iron shares are used, these, as they wear down, may be adjusted to any required depth. The plough, by this means, is made to retain always the same hold of the ground, and the share, according to the nature of the soil, may be made to work from four to eight inches deep. This plough was considered the best, lightest, and most workable that has yet been presented to agriculture.



## ELLIOTT'S WEIGHING MACHINE.

THE framework of this machine, which is manufactured by John Elliott, Sheffield, and a specimen of which was placed in the Great Exhibition, is a quadrant erected against the

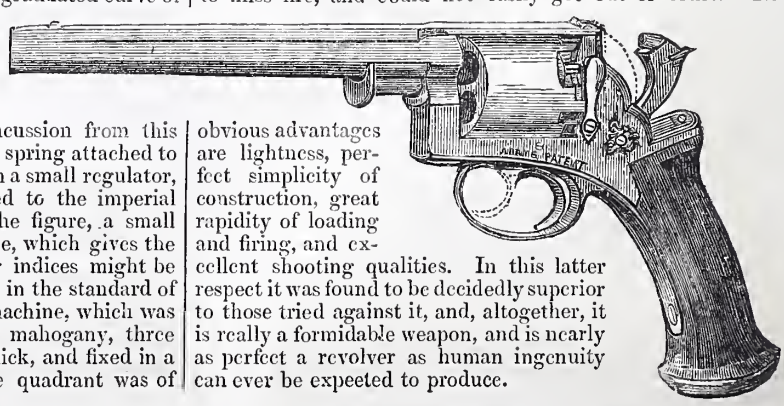


wall. The fulcrum of the balance projects horizontally from the right angle at the top. Attached to the balance are a weight and index, which move along the graduated curve of the quadrant, rising or falling according to the weight of the substance placed in the scale. When the scale is empty, the ball or weight attached to the index falls to zero on the quadrant. To prevent an injurious concussion from this sudden descent, the ball is secured upon a spring attached to the frame. The machine is furnished with a small regulator, by which it may at any time be adjusted to the imperial standard. There is also, as shown in the figure, a small index ingeniously attached to the balance, which gives the weight in French kilogrammes, and other indices might be attached, giving the corresponding weight in the standard of other nations. The framework of the machine, which was sent to the Exhibition, was of polished mahogany, three inches broad, seven-eighths of an inch thick, and fixed in a steel frame. The graduated scale of the quadrant was of brass. The radius of the quadrant was two feet four inches externally. The ball or weight attached to the index, was four inches diameter, and four pounds weight. The balance arm of the lever, to the radius of the quadrant, as one to six, and, consequently, the leverage as six to one of the ball. The machine is calculated to weigh from ¼ lb. to 56 lbs. avoirdupois; it may be made of various sizes, and is very convenient for all ordinary purposes.

## REVOLVER PISTOL.

BY DEANE, ADAMS, AND DEANE.

THE vast superiority of revolving fire-arms, as weapons offensive and defensive, is now universally admitted, and was fully ascertained, by experience, during the late Mexican war, when a handful of troops, armed with revolvers, were found to be more than a match for ten times their own number. A revolving pistol—of which a plate is annexed—has been patented by Mr. Adams, of King William Street, of the firm of Deane, Adams, and Deane, and attracted considerable notice at the Exhibition. Its powers were tested at Enfield and Woolwich by several officers of the army and navy, and other noblemen and gentlemen, who gave it their unanimous approval, as superior to any that have yet been invented. It admitted of ten discharges per minute, was found never to miss fire, and could not easily get out of order. Its



obvious advantages are lightness, perfect simplicity of construction, great rapidity of loading and firing, and excellent shooting qualities. In this latter respect it was found to be decidedly superior to those tried against it, and, altogether, it is really a formidable weapon, and is nearly as perfect a revolver as human ingenuity can ever be expected to produce.

# ILLUSTRATIONS OF MECHANICAL DRAWING.

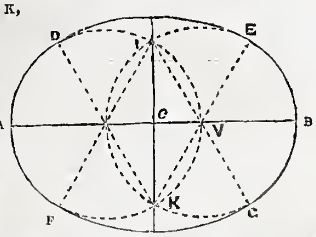
## CHAPTER IV.

A figure which is often substituted for the ellipse for practical purposes, but is decidedly inferior to it in point of regularity and beauty of contour, may be drawn by means of circles in the following manner.

1. Let A B be a given transverse diameter, divide A B into three equal parts by the points O V. From O and V as centres, with O A or V B as a radius, describe the equal circles D V F and E G O, cutting each other in the points I and K,

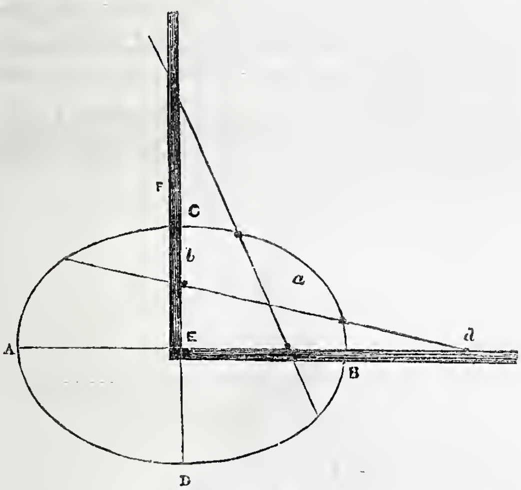
2. Draw the lines K O D, I V G, I O F, and K V E, cutting the circles in the points D E F and G.

3. From I and K as centres, with K D or I G as a radius, describe the curvilineal tangents D E and F G, when the figure A D, E B, G F, will be the ellipse required.




There are various methods of describing ellipses *mechanically*, at present in use, probably the best of which is that invented by Mr Ridley. By this instrument every species of ellipse, from a circle down to a right line may be correctly formed.

The instrument consists mainly of a beam *a*, carrying three sliding sockets, *b c d*, which may be set at any distance from each other. On the sockets *b* and *d* small sheaves are fitted to revolve on pins, and the centre one *c* is fitted to receive a pencil or tracer.

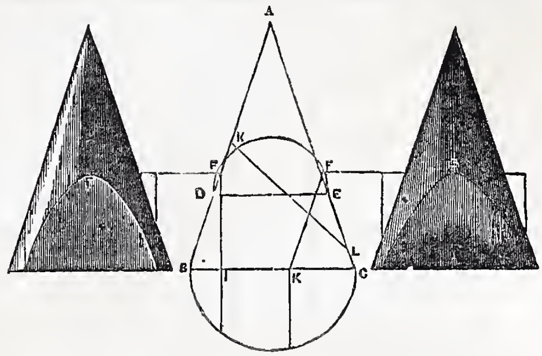



To explain the action of this apparatus, we shall suppose A B to be the transverse and C D the conjugate axis of the required ellipse, intersecting each other at E. The inner edge of a square F is now to be applied to the lines C E B, at such a parallel distance therefrom, as to allow the centres of the sheaves on the sliding bar to move exactly over the centre of the lines constituting the axes of the ellipse. To adjust the position of the sockets to produce the given ellipse, the distance between the pencil and the sheave *b*, is made equal to half the length of the transverse axis, and *c d* equal to half the conjugate. If now the bar is moved along the edge of the square as shown by the dotted lines, the tracing point will describe one quarter of the ellipse, each of the remaining portions being described in a similar manner.

This simple apparatus has since been considerably improved; instead of the plain square of wood, two grooved pieces of metal crossing each other at right angles, so as to form four squares, are substituted. The pins in the pencil beam are fitted to slide in the grooves which are made along the upper side of the squares. In this manner, the whole of the ellipse may be described at once, with the exception of the slight portion which the thickness of the square covers; these are easily filled in by hand.

We now come to the consideration of the two curvilinear figures, the parabola and hyperbola, which, together with the ellipse, are generally treated under the head of Conic Sections, that is, as curves produced by the intersection of a flat surface with the curve surface of a cone.

Let A B C represent a vertical section through the centre of a cone, the figure which is produced is a triangle.

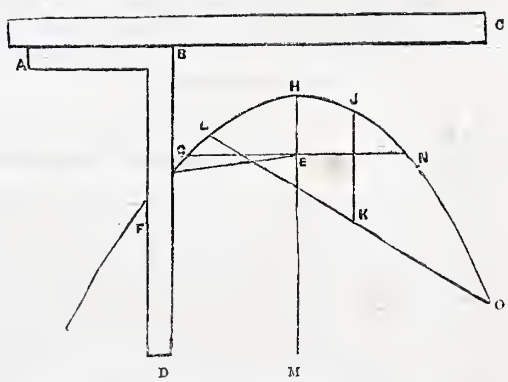



If the entire cone is cut by a plane passing through it in the direction of D E parallel to the base, the figure produced will be similar to the base, that is a circle.

If the section is made in the direction, F K, parallel with the opposite sloping side of the cone, as A B, the curve described on the surface will be a parabola. If the intersecting plane pass through the cone in the direction, F I, perpendicular to the base and parallel to the axis, the curve produced on the surface of the cone by the section is an hyperbola.

If the intersecting plane pass through the cone in any oblique direction, as K L, the curve described on its surface will be an ellipse. As we have already explained the construction of the ellipse, we shall now proceed to examine that of the parabola.

In order to enter fully upon the geometrical construction of this figure, we shall in the first place exhibit its mechanical formation, so as to enable us to set before the student the most explicit rules for application in practice.




In the annexed figure, let A B C be a straight-edged ruler, and A B D a common joiner's square; and let a thread of a length equal to B D be fixed by one extremity to the end of the square D, and the other to any point, E, between the two rulers. If now the side A B of the square be moved along the edge of the ruler A B C, and a pencil is applied to the edge B D, so as always to keep the thread stretched, at the same time that it allows it to slip round its point F, the pencil will describe a curve, F L H I, which is a parabola.

The point, E, about which the thread moves, is called the *directrix*.

A line, H K, drawn through the focus E, and perpendicular to the directrix, is called the axis of the figure.

The point H, in which the axis cuts the curve, is called the *vertex* of the figure.

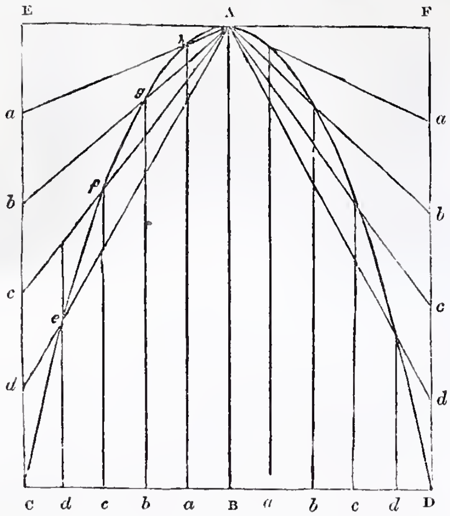
A line, G N, passing through the focus E at right angles to the axis and terminated by the curve, is the *parameter*.

Any line which can be drawn within the limits of the curve, parallel to the axis, as J K, is called a *diameter*.

If a tangent were drawn to J K at J, the extremity of the diameter, a line, L O, drawn parallel to it, is called a *double ordinate*

That part of any diameter, which is contained within any part of the curve itself and its ordinate, as J K, is termed an *abscissa.*

Problem XXII.—Let A B be the given axis of a parabola, and C D a double ordinate. It is required to delineate the curve, by a process, which shall determine a number of points in its course.




1. Through A draw E F parallel to the double ordinate C D. Through C and D draw the perpendiculars C E and D F parallel to A B

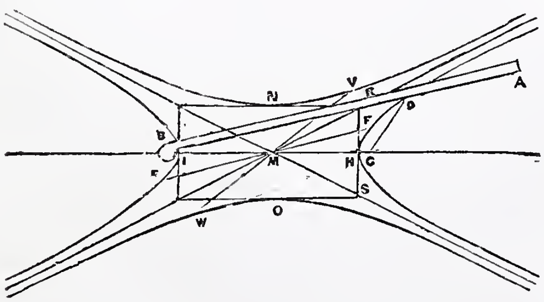
2. Divide B C and B D into any number of equal parts, as five. Likewise divide C E and D F in a similar manner.

3. Through the points *a b c* and *d* in C D, on each side of the point B, draw the perpendiculars *a e b f c g d h*, &c., and through the points *a b c* and *d*, in C E and D F, draw lines to the upper extremity, A, of the transverse axis A B, respectively cutting the perpendiculars drawn from the line C D, in the points *e f g h*, then will the points of intersection to the right and left of the transverse axis be situated in the curve of the required parabola, and which will be completed by tracing a line steadily through them.

### Of the Hyperbola.

In giving a familiar explanation of the properties of this curve, we shall again have recourse to the mechanical process of its formation to the end, that we may the more easily define its leading characteristics.

Referring to the accompanying wood-cut, we shall suppose the points B and C to be determined, and a straight ruler, A B, to be made moveable on one of its extremities, about the point B, as a centre. To the end, A, of this ruler one end of a thread is attached, the other being fixed at the determined point C. Now, let a pencil be applied to the thread, so as to press a portion of it against the edge of the ruler, as A D, and keep the other portion, D C, tightly stretched. The ruler being made to traverse on the given point B, at the same time that the pencil D moves along its edge, always preserving the tension of the threads; and the motion of the pencil or point D will be in the curve D F G, which is that of an hyperbola




If the extremity of the ruler, which now moves on the point B as a centre, was removed to C, and there made to traverse in a similar manner, the end of the thread now set at C being now placed at B, the curve described would be an *opposite hyperbola.*

The points B and C on which the ruler traverses are called the *foci.*

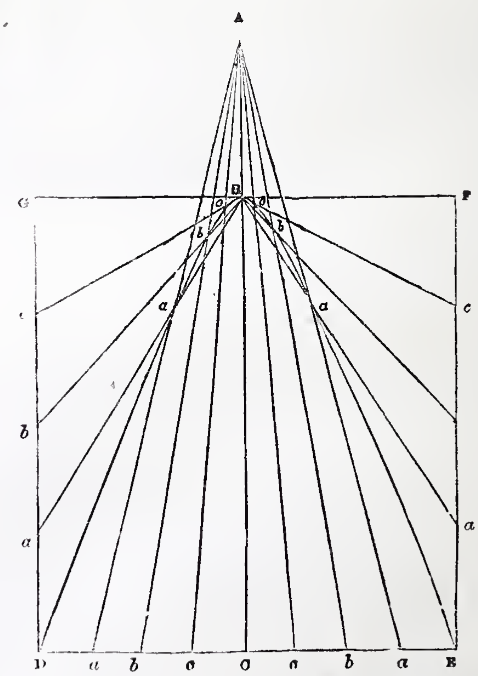
A line terminated by the curves of the hyperbola and its opposite, and which, if continued at either extreme, would pass through either of the foci, as I H in the figure, is called the transverse axis. A line passing through the centre M of the figure to the right and left of it, and terminated by the intersection of the arc of a circle, which is described on the point H as a centre, with the distance C M as a radius, is called the *conjugate axis.* Any line, as V W, drawn through the centre M, is called a *diameter.* If a tangent with either of the curves be drawn to the extremity of V W, another line, as F F, drawn parallel to that tangent and through the centre M, is called a *conjugate diameter* to that at the extremity of which the tangent was drawn. A line drawn through any diameter parallel to its conjugate diameter and terminated by the curve, is called a *double ordinate.* If any diameter be continued within the curve, and is terminated by the curve and a double ordinate, the part within is termed an *abscissa.* A line drawn through the focus of the figure, and at right angles to the transverse axis, is called the *parameter.*

If through the extremity of the transverse axis, I H, a line, R S, is drawn parallel to the conjugate axis N O, and equal to N O, having H R and H L respectively equal to M N and M O, their right lines drawn through the centre M, and the points R and S, as are the lines M X and M Y, are called *asymptotes.*

When the transverse and conjugate diameters are equal, the hyperbola is termed *equilateral* or *right angled.*

The recapitulation of these dry and uninterestiug terms may appear formidable to the student, but he must bear in mind that a complete knowledge of these is essentially necessary to enable him to comprehend and construct any hyperbolic curves with which he may meet in practice. For curves of a large size, the foregoing mechanical system of construction is very useful and accurate; but, as before adverted to, in order to attain a complete knowledge of the subject, as well as to be able to cope with the different forms which occur, it is necessary to understand correctly their geometrical construction.

Problem XXIII.—The diameter of an hyperbola, A B. Its abscissa, B C, and double ordinate, D E, being given, it is required to delineate the curve by determining a certain number of points which shall be in its course.



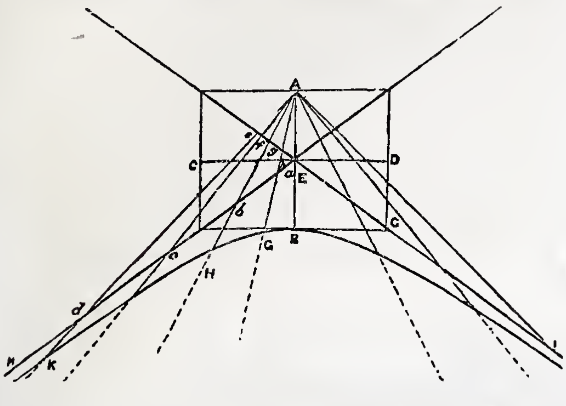

1. Through B draw G F parallel to D E, and from the extremities D and E, of the ordinates, draw D G and E F parallel to the abscissa, B C, cutting G F in the points F and G.

2. Divide C D and C E, each into any number of equal parts, as four; and through the points of division, *a b c*, on each side of the point C, draw lines to A.

3. Divide D G and E F into the same number of equal parts, and

from tho points of division, on D G and E F, draw lines to B. A curve drawn through the intersections at *a b c* on each side the diameter, will be that of the hyperbola required.

Problem XXIV.—The transverse and conjugate diameters, A B

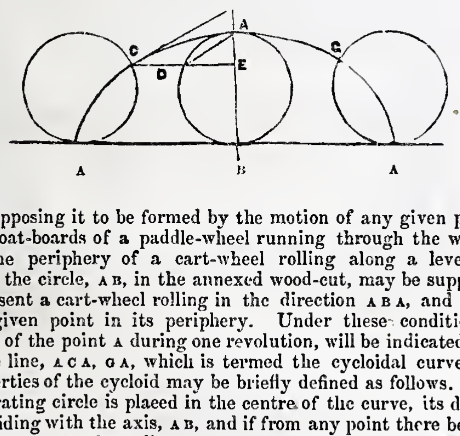



and C D, being given, it is required to determine a certain number of points in the curve, with a view to its delineation.

Through the extremity, B, of the diameter, A B, draw F G parallel to C D, the other diameter; and make B F and B G equal to the semi-diameters E C or E D. Through the points F and G thus determined, draw E H and E J, which will be the symptotes of the figure.

From A, as before, draw lines at pleasure towards the curve to be described, as A G, A H, A J, A K, cuttitg the asymptotes at the points *a b c d* and *e f g* and *h*, &c. Set off the distances A *h*, H *g*, A *f*, A *e* respectively from the points *a b c* and *d* on the lines from A; and the points G H, J K, will be in the curve required.

If the student has gone over this course of practice in the construction of geometrical curves, by performing the examples themselves on a large scale, he will be enabled in his future operations to make use of them in any drawings which come before him in his every day practice. There are numerous other useful curve lines which admit of regular definitions, as the Cycloid, Epicycloid, Catenary Curve, &c. The Cycloid may be defined in a familiar manner,



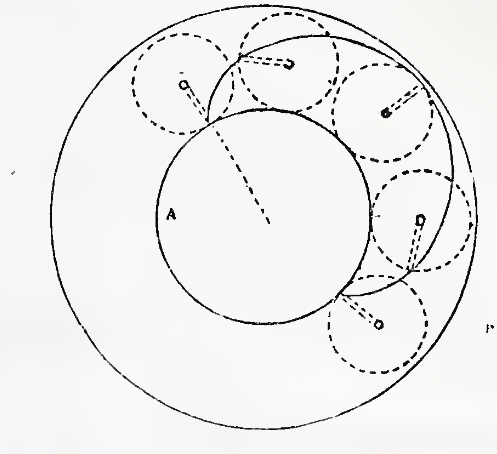

by supposing it to be formed by the motion of any given point on the float-boards of a paddle-wheel running through the water, or on the periphery of a cart-wheel rolling along a level road. Thus the circle, A B, in the annexed wood-cut, may be supposed to represent a cart-wheel rolling in the direction A B A, and A to be the given point in its periphery. Under these conditions the track of the point A during one revolution, will be indicated by the curve line, A C A, G A, which is termed the cycloidal curve. The properties of the cycloid may be briefly defined as follows. If the generating circle is placed in the centre of the curve, its diameter coinciding with the axis, A B, and if from any point there be drawn a tangent, C E, the ordinate, C D E, perpendicular to the avis, and the chord of the circle, then

The right line C D = the circular arc A D.
The cycloidal arc A C = double the chord A D.
The semi-cycloid A C A = double the diameter A B, and
The tangent, C F, is parallel to the chord, A D.

If the ball of a pendulum is caused to move in a cycloidal curve, its vibrations will be isochronous, that is, they will all be performed in precisely the samo amount of time.

The epicycloid differs from the cycloid in this, that it is generated by a point in one circle rolling upon the circumference of another, instead of a level surface. The cycloid may, however, be brought under the same definition by regarding the straight line as the circumference of a circle whose diameter is infinitely great.

This definition of the curve will be understood by reference to the accompanying figure, in which A is the *generating* or rolling circle, and B the *fundamental* one, or that upon which it rolls in describing the exterior epicycloidal curve, C D. If the generating circle, instead of rolling on the outside, were to roll within the interior circle, a point in the former would describe an interior epicycloid, or, as it is more recently termed, the hypo-cycloid.




This curve was proposed, about the year 1674 by Romer, the Danish Astronomer, as the proper form for the teeth of wheels, in order to avoid rubbing friction, and it is now the fundamental principle upon which all toothed gearing is constructed. A beautiful example of the application of the interior epicycloid, as a parallel motion, will be found in White's Century of Inventions.

## HARRISON'S IMPROVED POWER-LOOMS.

In nothing has the rapid march of modern improvement been more obvious than in the construction of the power-loom. Two of these machines, with all the latest improvements, were sent to the Great Exhibition (Class VI., No. 18) by Mr. J. Harrison, Bank Foundry, Blackburn. One was a loom adapted for fabrics of light materials, as cotton, wool, and flax, and for tweeled goods up to four leaves; the other was a loom for heavy and tweeled goods. Accompanying these improved machines was an old loom, made about fifty or sixty years ago at Abbey Mill, Paisley, and very similar to the power-looms at first worked in that district, in 1796, by Mr. Robert Miller, of Milton Pruffield, near Dumbarton. To show the immense improvements which have taken place in the design and manufacture of these machines, we may state that the old loom, which, when first introduced, was considered a miracle, was only capable of running with advantage *sixty picks*, or throws off of the shuttle, per minute, besides requiring the constant attendance of one person for each; whereas the new looms may be driven at the rate of 220 picks per minute, and, by the application of several improved motions, one person is enabled to attend to two, and, in some cases, three looms at once.

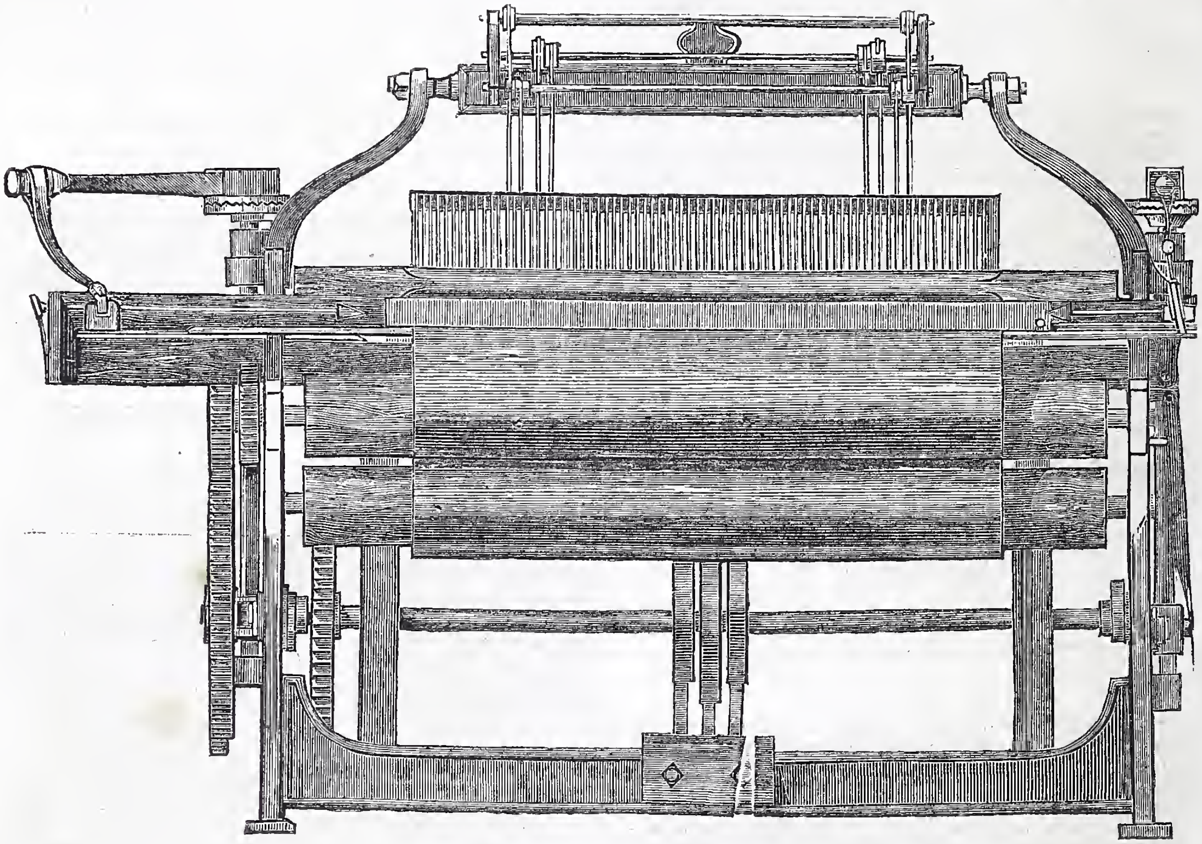
The principal improved motions, as these were exhibited in Mr. Harrison's looms, are respectively known as the "weft protector," the "temple," the "positive taking-up motion," the "loose reed and break," and the "fast reed and break." The weft protector and the temple motions have been patented by Messrs. Kenworthy and Bullough, of Blackburn, the loose reed and break by Mr. Bullough, and the fast reed and break by Mr. John Sellers, of Burnley. We shall give a short account of the nature of each of these contrivances:—

The "weft motion" is a simple and ingenious device for stopping the machine when the thread breaks, or happens to be absent from its place, so as to prevent it from weaving without weft, which would entirely damage the piece, by

leaving a part of it unfinished. The contrivance consists of a small fork, which acts in connection with the setting or handle of the loom, and by which the machine is immediately stopped when a break or fault occurs from either of the causes above mentioned. This motion, therefore, dispenses with the great care and vigilance hitherto required on the part of the operator, and benefits both himself and his employers, by enabling him to produce more cloth in a given time.

The "temple" is a long semi-cylindrical box or trough, into which is fitted a roller, cut or fluted to nearly one-third of its length at either extremity, after the manner of a file. This roller rotates on the box, and its use is to keep the fabric at one uniform width throughout the piece, and the sides free from holes and rents, by which means the whole fabric assumes a more finished appearance. There is also a "temple" in the old loom, to which we have already referred, but it requires the aid of the operator to move it, and this demands his constant attention to prevent it from moving with the fabric, and thus becoming perfectly useless, besides tearing and perforating the sides of the cloth, as not unfrequently happens.

The object of the "taking-up motion" is to insure uniformity of thickness throughout the piece. By the application of a small wheel, containing a certain number of teeth or cogs, acting in connection with three other small wheels and the cloth beam, it regulates the number of threads of weft in a given space. By this contrivance the cloth beam, at one and the same time, folds up the cloth, and moves it so as to insure the desired thickness throughout. The fabric might otherwise present different thicknesses throughout its texture, which would, of course, be a very great blemish.



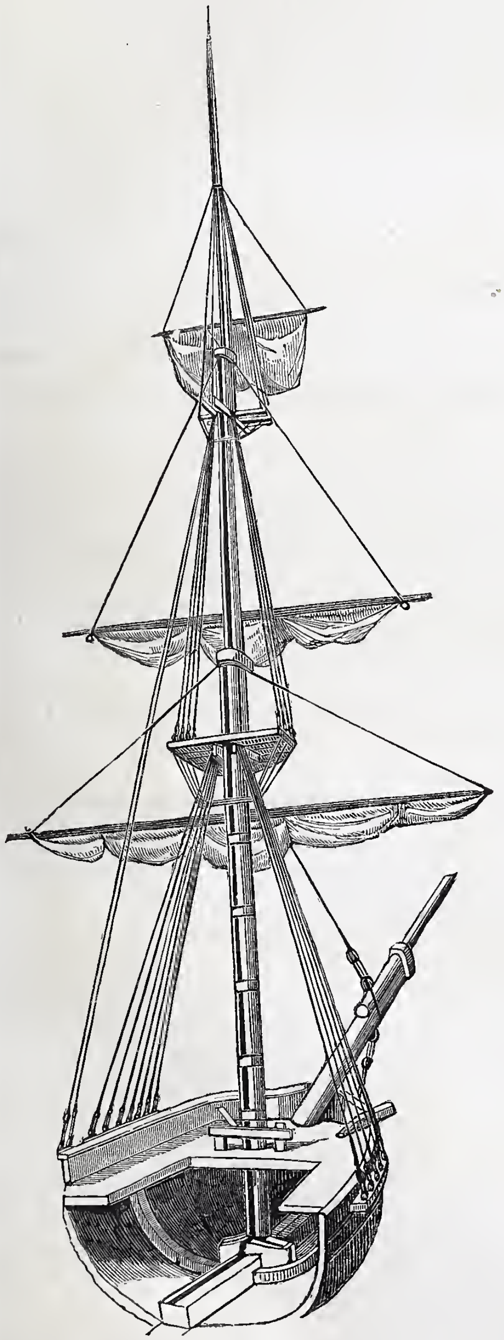
The "loose reed and break" of Mr. Bullough, and the "fast reed and break" of Mr. Sellers, are, respectively, the most suitable for light and heavy fabrics. By Mr. Bullough's invention the great destruction of threads is prevented, which usually happens whenever the shuttle fails in traversing the sley from one end to the other. Where this invention is applied, the loose reed falls out at its place, and gives way to the shuttle. By this simple and ingenious expedient, any derangement or breakage of the warp is prevented. The fast reed and break is a somewhat similar contrivance, suitable for heavy goods.

There are other important movements, which are almost equally effective to the perfect and complete working of the power-loom of the present day; but those which we have mentioned are the leading and characteristic improvements of more modern date. Their value will be understood when we state, that by the old loom, with twice the amount of labour, not more than one-third the amount of cloth could be produced, as compared with the working of the new looms, in a given time, and that of inferior beauty of texture. From two of the improved looms in a factory, working sixty hours per week, an experienced operative will produce 26 pieces, 29 inches wide and 29 yards long, of printing cloth of *eleven* picks per quarter inch. The weaving of each of these pieces costs only 5½d. If set to work at one of the old looms, the same person could only produce four similar pieces, each of which would cost 2s. 9d. for weaving alone. The saving effected by the new looms, in weaving alone, is therefore incalculable; and it is by such contrivances, promptly applied, that this country is enabled to maintain her vast superiority over the rest of the globe in the production of cotton goods and other fabrics.

## SIR WILLIAM SNOW HARRIS'S LIGHTNING CONDUCTORS FOR SHIPS.

THE system of conductors now employed to protect her Majesty's ships from lightning, is that invented by Sir W. S. Harris, and has hitherto proved so entirely efficient, that, since the employment of this system in the navy, no damage

Fig. 1.



from lightning has been recorded. The object of conductors generally is to present a passive medium of transmission to the electric discharge, which assumes the form of a violent explosive action, exhibited in the effects of lightning, when it is obstructed in its progress by some resisting matter, such as air, vitreous and resinous bodies, wood, cordage, and other substances, known as imperfect conductors. The principle on which the inventor proceeded in devising his system of conductors for ships was, therefore, to arm the vessel, as far as possible, with such a complete mechanism for transmitting the fluid, as if the entire mass were metallic throughout, so that when struck with lightning, on any portion of the masts

Fig. 2.

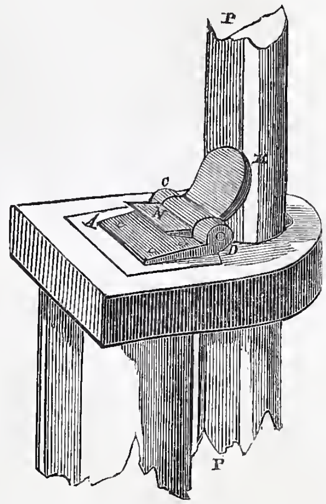
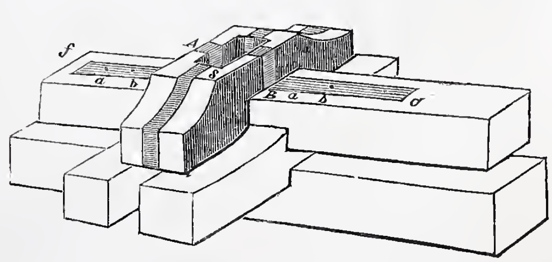


Fig. 3.

aloft, the explosion might instantly be converted into a quiescent discharge, and pass through the vessel into the water. The difficulty in effecting this—which the inventor succeeded in overcoming—was to admit of the system of conductors being permanently fixed, throughout the whole extent, without interfering with the perfect motion of the sliding masts one on the other, without interfering with the standing or running rigging, and without losing its protecting power by the removal of any part of the mast, whether from accident or design. These important points are completely secured by Sir William Harris's conductors, which thus possess the essential advantage of being entirely independent of the officers or crew of the ship. The ordinary operations of the vessel do not interfere with them in any manner, and even an accident may happen to the mast, or part of it be entirely removed, without impairing the protecting power of the conductors. They are likewise so constructed as to offer a sufficient resistance to any accidental violence to which they may chance to be sub-

Fig. 4.



jected, while, at the same time, they yield without injury to any flexure or strain incidental to the spars or other parts of the vessel to which they are applied. The sailors are never required to handle or replace them—an operation

which is sometimes attended with danger as well as difficulty —and yet, so completely do they invest the ship that the electric fluid can scarcely touch upon it on any point, without coming into contact with some part of the series in its course to the sea.

The practical efficiency of this admirable system of conductors has been proved in numerous cases. When H.M.S. *Conway*, 28, was refitting at Port Louis, Isle of France, 9th March, 1846, the lightning struck a spar which was set up at the top-mast head as a temporary support to the pendant, the top-gallant mast being on deck at the time. The spar had consequently no conductor. The report of the thunder was loud, and is described as if one of the main-deck guns had been fired. The only damage done was the shivering of the spar in pieces by the explosive action, when the fluid immediately reached the line of conduction and passed off quietly into the sea, without injuring the gunner, who was sitting in his berth immediately under one of the lateral branches of the conductor passing through the ship, and who saw through the scuttle-port a brilliant blaze of light from the ship into the sea. He experienced no inconvenience whatever. The following is the official record of this occurrence:—"Port Louis, Isle of France, 9th March, 1846, 11.45 a.m. The pendant staff at main-top mast-head was shivered in pieces by lightning: Harris's conductor carried off the fluid without farther damage."

Practical models, illustrative of this system of conduction, were displayed at the Great Exhibition, Class VIII., No. 150. The accompanying diagrams will give a sufficiently accurate idea of the chief peculiarities of its construction:—

Fig. 1 shows the line of conduction on the masts from the vane spindle to the step.

Fig. 2 represents the moveable tumbler at the junction with the caps, in which A D is a copper plate fixed on the cap; M N an angular plate set on the hinge, C D; P, the conductor on the mast. This hinge is sometimes covered with a small saddle of wood, to prevent its being damaged.

Fig. 3. The vane spindle; in which *s t* is the portion inserted into the royal mast; *s*, the thread of a screw for securing it; D, a thick cylindrical base, with a hole at D for a small lever.

Fig. 4. The step of the mast and portion of keelson; A B, M N, the transverse and longitudinal branches passing round the step, and through the mortice at S; *f c*, the branch over keelson; bolts, *a b c*.

## THEORY AND PRACTICE.

We have two very active and useful classes of men—the theoretical and the practical—between whom a contest for precedence has long existed. The contest is usually regarded as of little moment; and, it must be admitted, that there would hardly be a plea for interfering, were it not that their mutual jealousies defraud us of no small amount of their several contributions to the stock of our knowledge. It is on this account not an entirely harmless contest, nor are the depreciatory opinions entertained of each other, without their injurious effects. This is not difficult to perceive, when the mutual relations in which the parties stand to each other are considered. To understand these relations, however, it is necessary to know distinctly in what theory and practice essentially consist.

Nothing is more common than to hear that a thing may be right in theory, but decidedly wrong in practice, and the proposition is very commonly assented to by seemingly sensible men. Are we then to suppose that these terms are really antithetic—that theory and practice are essentially distinct and opposite? No proposition could be further "wrong in practice," or more clearly belie the common meaning of language. What is a theory? Example,—"*All matter has weight.*" Surely this announcement is not in opposition to the practice of the grocer. It might seem to contradict that part of our experience by which we know that a balloon, with its attendants and apparatus, will ascend five miles into the atmosphere; but here theory again steps in, and announces that "All bodies immersed in a fluid of greater specific gravity than themselves will ascend, unless restrained." This at once removes the difficulty, and contradicts nobody's practice; for experience informs us that our atmosphere is a fluid of considerably greater density than the gas by which the balloon is inflated.

The relation then which exists between theory and practice is not that of opposition and contrast; it is a relation of simple comparison. Theory is, in fact, generalized practice —it is the results of experience reduced to system, and imbodied in general language. In other words, it is the principles of correct practice, and without reference to practice it could not exist. To apply the term to what is not practicable is absurd; and to use it otherwise than in the sense of the best possible practice is to divert it from its legitimate and true meaning.

The true distinction which is to be recognised between theory and practice as terms of language, is, that practice describes a set of operations which have not been methodized and reduced to a systematic form. Theory, on the other hand, is the name under which a class of operations is generalized, and their principle enunciated. While practice indicates a certain mode of action, theory points out the most correct way. And, if this be correct, our next conclusion is, that practice, unaided by theory, has only a *chance* of being right; whereas theory can never be wrong; and that practice, which is not entirely in accordance with theory, must be erroneous.

It must be allowed that this is rather the strict meaning of the term than the signification which it is often made to bear. But the employment of it to denote that sort of philosophical guess-work called *hypothesis* is unphilosophical, although often *practised*. Hypothesis and theory are essentially different; the hypothesis *may be* correct, but the theory is essentially true. What is false has no place in theory, and can form no element of theoretical knowledge; an hypothesis may be entirely erroneous and contrary to the truth. We need not go to history for illustrations of this; we have many hypotheses in practice, and, in short, our whole aim is to reduce practice to theory, and free it from the hypothetical mixture which enters so largely into its constitution.

Every practical mechanic, and indeed every member of society, whatever may be his position, has then an interest in the extension of theoretical knowledge. Theory is the model to be taken for imitation, and it is upon this imitation that all dexterity is founded. If the process as a process of art be new, the model may not have been brought under actual observation; but it must exist in the mind. It may there be mixed up with hypothesis, and, to that extent, it is doubtful. To imitate what has been done before is practice, but there is a disposition in the mind to surpass this imperfect sampler; for, all human operations, even the best performed, fall short of absolute correctness. But whatever extends beyond the degree of accuracy with which like work has been previously performed, is theory. Practice goes no farther than human ingenuity has previously done. It stops short when it has reproduced the work with all the imperfections of the model, and beyond the degree of accuracy necessary to accomplish this it cannot proceed without taking a theoretical model—a model free of blemish—as the object of imitation. No practical man, if he harbour the slightest desire for improvement in his operations, can therefore avoid theorizing, however unconscious he may be of the mental process applied. All that admirable accuracy, which characterizes the tools of the work-shop—all those improvements in the arts of which we are so justly proud—all that delicacy and beauty of workmanship which we point to with exultation—all that skill and dexterity, all that knowledge and ingenuity which the products of our industry exhibit, are the results of that quenchless thirst for theoretical knowledge which actuates the mass of society as one common motive. The value of theoretical knowledge may thus be regarded as

coextensive with the desire of improvement, and the tendency of every man to theorize may be regarded as one of the primary feelings which go to form the mental constitution of the individual. Be a man's vocation what it may, the ambition of his mind is to make constant progress in his art—to set up for imitation a perfect model, and to press forward towards completeness. In this way the idea of perfection takes root in the mind, spreads beyond the mere vocation, and finally renders whatever is slovenly in any department of life offensive and disagreeable.

Beyond the facility of repeating what has been imperfectly done before, practice then does not go. It stops short when it has brought the muscular action under that control which is necessary to the performance of a class of often repeated operations. It aids us nothing in improving on the lessons which have been set. The moment we take our position on higher ground—that moment we step beyond the training of mere habit; practiee becomes theoretical, and a new impulse is given to improvement. Theory without practice cannot, indeed, exist among the arts of life; and without the acquisition of that dexterity, which is necessary to the working out of the principles upon which the operations depend, all theoretical knowledge would be useless, because impracticable. Thus far, then, is practice essential; but facility of operation once attained, the man who is familiar with the theory of the operation—he who compares the results of his labour with other results, and discovers the connexion of the particular operation to which it belongs—is in a condition to apply his dexterity more extensively, and with increased effect. He becomes, in consequence, not only a more valuable workman, but a more dignified being than before. He shoots a-head of his compeers; and, rising in the scale of intelligence, he sets up a model for practice which may stimulate to further and higher improvements. Following up the sleepless principle of his nature, he stamps upon his art the impress of his intellect, and takes his place as a benefactor of his race.

But the practical man is not the only gainer by the dissemination of theoretical knowledge in alliance with practice. All work requires for its successful execution a combination of labour, and as processes approach more and more to a state of completeness—society at large is benefited. There is a feeling, indeed, that the practical mechanic has become, by the progress of improvement, a mere tender of machines; and, therefore, requires little more intelligence than to know the order of the wheels, pulleys, levers, and cranks, under his superintendence. Nothing can be more wide of the truth, and no opinion, were it acted upon, could be more hurtful to the progress of society. Machines are the tools by which we employ the powers within us, and the external powers which nature has placed at our disposal. They aid our industry, and enable us to perform what could not otherwise be accomplished, but can never supersede intelligence. It is the governing hand of man which infuses usefulness into their movements. Without this they were worthless; the facilities which they give are the return which they make for the ingenuity and thought employed in planning and constructing them, and for the care and attention bestowed upon their superintendence. Moreover, although many of them are excellent, yet few can be pronounced beyond the reach of improvement, and still fewer can be ranked as perfect. If, then, there be little room for improvement in superintendence, there is still an ample field in their forms of construction and the accuracy of their workmanship. And here theory is the only guide. Its deductions may not, in practice, be realized in full, but the more nearly we approach that point, the more closely do we approximate to perfection.

It is, then, manifestly impossible to separate practice from theory, without relinquishing every prospect of advance, and every hope of amelioration. Theory is the basis of all progress, and the disrepute in which the term has been held by practical men—all theorizers, nevertheless—has, in some measure, arisen from its placing models before him which he found it was impossible at a first trial to copy. In his haste to condemn, he likewise not unfrequently forgets that many improvements are often necessary to be made, before that special one at which he aims can be attained. He forgets that, but a few years ago, the common operations of the lathe and the planing-machine, which are now within the range of his every-day practice, were reckoned unattainable. They were then theoretical; they are now illustrations of the advantage which practice reaps by following in the path of theory. Railways, and all the ideas we associate with them, existed but a few years back in theory, and the whole aggregate achievements of the steam-engine, are but so much practice derived almost wholly within our own recollection, from the deductions of theory.

It frequently indeed happens that theories propounded by non-practical men are defective, are wanting in some of their important elements. Such propositions are, however, incorrectly called theories, for theory must ever be perfect. Much, however, of the mistrust which besets the term has arisen from this false application of it. It belongs, therefore, to the practical man to correct these so called theories—take from them those elements which are valuable, and which he has overlooked in his practice, and ingraft them upon his own stock of knowledge. It is in his hands that theory becomes useful, and he deprives himself of much of the means of advancing himself and his art by continuing to treat with disdain all deductions of a scientific kind, because they have not, hitherto, been reduced to practice. It is, moreover, upon the data which his art furnishes that a theory of his operations can be founded. He ought not, therefore, to blame the merely theoretical inquirer because he has failed to incorporate every element of the investigation. He is unworthy the name of a theorist if he has not made good use of the materials which he has collected, and where the deficiency occurs the practical man must supply the omission. This function, however, implies in the practical man more than mere practice—it implies a knowledge of the theoretical truths upon which his practice is founded; and should these be wanting, he is not certainly entitled to throw contempt upon the pioneers who would instruct him in the science of his calling.

In strictness, theoretical knowledge ought not only to be the foundation of all practice, but it ought to be regarded as such, and acquired as such by the practical man. Superior success in every operation he undertakes, depends upon the extent to which he succeeds in taking theory as his guide; and failure as certainly marks his ignorance or neglect of the injunctions which it imposes. Nothing could be more at variance with truth, than the supposition that practice stands out alone, and distinct, and independent of all principle—of all theory. Besides, there are, as yet, but few of our arts —advanced as they confessedly are—in which we can affirm that progression has taken the last step. We cannot, indeed, assert that we have gained a full knowledge, even of the properties of the vapour of boiling water, and it is even possible that a time may come, when all our boasted achievements in locomotion, on land and water, shall be regarded as the feeble and partial attempts of dawning knowledge. The announcement that a new power had been developed and bequeathed to art by science, is hardly yet dry upon the pages of our journals. Little progress, it may be said, has hitherto been made in the applications of electro-magnetism; but this is no argument that it is a supernumerary and useless bequest. Within a less period than has been requisite to develop our present knowledge of the applicability of steam power, it may have become the moving force of all our factories, and the agency by which our descendants shall traverse the ocean, and on land, bring together the distant corners of our island. The power is given, and it now belongs to practice to render it applicable and beneficial to man. If it be true, that no function and no property have been given to matter needlessly, we have much reason to hope, that under the strong dominion of man's intellect, it will be made to put forth its energies for his advantage and in his service.

The object of all our industrial ambition is to bring the

powers of nature more and more thoroughly under our control. We are placed in a position in which there is much to admire; but our admiration is limited by the extent of our knowledge of those physical laws which control our circumstances, and regulate our well-being. The great powers of nature are subservient to us, but it is still doubtful whether we have obtained from them a full return of the vast amount of benefit which they are calculated to confer; and until we are certain that the final step has been taken, there is room for improvement and scope for theorizing.

But while we blame the conduct of the practical man who makes a pretence of despising the labours of the theorist, we have likewise a word of admonition to those who would set up theory as something sacred—something that must only be approached by those who have passed through an extended curriculum of mathematical study. "A little learning," they tell us, "is a dangerous thing," and "shallow draughts" of knowledge are worse than ignorance. But with all due deference to "college lore," we would ask whose "learning" is not "little," and whose "knowledge" is not "shallow." The expansion of the widest intellect is narrow, but all knowledge is valuable, however shallow, and all truths are gathered within a little nook of creation. The ability to read and apply the formulæ in which the theorist gives forth the results of his investigations may not be very intelligible to the practical mechanic; yet he has a thousand truths in store, which he understands better, and comprehends more thoroughly, than abstract theory can ever hope to expound. There are, moreover, but few theories which bear the stamp of perfection—few are entirely complete. There is some element assumed, or some element wanting. Bodies are assumed to be perfect in the properties assigned to them—practice finds these properties mixed up with others, which find no expression in the theory propounded. It is in the valuation of these mixed qualities that the superiority of practice consists, and, in the estimation of these, practice will be superior to abstract theory, until these so-called irregularities are brought within the range of calculation.

## NATURAL PHILOSOPHY AND CHEMISTRY.

### CHAPTER XI.

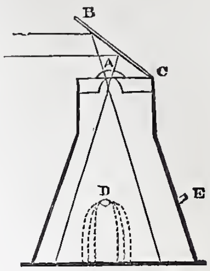
#### DIFFRACTION AND INTERFERENCE OF LIGHT.

We have already seen, under the head of refraction, that the pure white light of the sunbeam is composed of coloured rays—red, yellow, and blue; and that these elementary rays can be separated, and again reunited to form colourless light. The experiments described are conclusive of these facts; and, were there no others in reserve, we might still be satisfied that we had advanced very far towards a knowledge of the physical constitution of light; and might with propriety regard our explanation of the phenomena of colours complete and unquestionable.

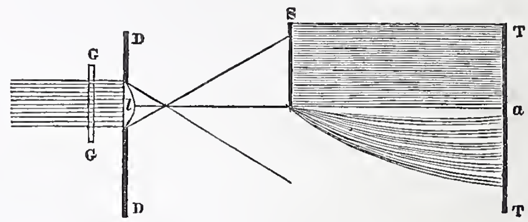
Refraction and absorption are not, however, the only methods of decomposing light: they are the most obvious and best known, and, therefore, deserve our first attention; but there are circumstances under which light suffers decomposition, differing entirely from those described, and presenting a series of phenomena of great interest and of the utmost value in the present state of optical science.

We have found that a beam of light transmitted through a prism, gives an oblong coloured image of the sun, upon a screen placed to receive it; but if, in this experiment, we remove the prism and substitute for it a small rod—a pin, for instance—we shall find, on each side of its shadow, a series of coloured fringes,—the first presenting all the seven prismatic colours in their order; the second, the three primary colours; and the third the same colours, but of a paler shade. If we examine the shadow itself, we shall find that it also is divided by parallel fringes, which vary in number and in breadth according to the distance of the body from the shadow that is examined.

The most satisfactory mode of making this experiment upon a small scale is, with a pyramidal box like that depicted upon the margin. The box is two feet long, and painted black inside. It has a small convex lens A, of short focal length, fitted into the cover, and on this, by means of a mirror B C, a sunbeam can readily be thrown. The light is refracted to a point, and then diverging, is received upon a sheet of writing paper placed upon the bottom of the box. A strong hair D, is stretched across the box, and through a small tube at E the bottom and chromatic phenomena upon it are viewed. The fringes are denoted by the dotted curves falling from D.




There is a still more striking form of this experiment. It may be performed with the apparatus described above; but, for the sake of distinctness, we shall suppose that the light is admitted into a darkened room, through a small lens placed in a shutter of the window. Let us suppose, further, that light of only one




colour is allowed admission. To ensure this it is only necessary to place a plate of glass G G, of the proper colour, without the lens. This arrangement being completed, and a white tablet T T, placed to receive the light—if at a little distance from the focus of the lens a screen S, whose edge is thin and clear, be fixed in the position shown, its shadow above the geometrical boundary line *l a*, will not be total darkness, but will be sensibly illuminated to a considerable distance by a faint light, diminishing almost uniformly in intensity. Below this line, on the contrary, will be observed alternations of light and dark. The first is a bright band, parallel to the edge of the screen and exceedingly brilliant. This is succeeded by a dark band, very black, and parallel to the first. This is called the black fringe of the first order. Then comes a second bright band, and then a dark one, which is black, of the second order. This succession continues to a considerable distance from *l a*—till, indeed, black fringes may be observed, under favourable circumstances, of the sixth or even of the seventh order. In the mean time, the bright bands become less and less brilliant, until they are lost in the light which passes the edge of the screen.

It is plain that the bands take their rise at the edge of the screen, for if their path be accurately traced, it will be found to be curved; and very exact measurement determines the curves to be hyperbolas—represented in the figure upon an exaggerated scale. All the colours of the spectrum produce this effect, with only this difference, that in passing from the red to the violet, the bands become narrower and narrower, but are always distinct. It is for this reason that white light, in the former experiment, does not give black and white fringes, but fringes of different colours, arising from the mixture of the prismatic colours in different proportions.

These phenomena must, then, depend on the bending of light in some way or other, and takes the general name of *diffraction*. The remarkable shadows described are from the name of the philosopher who first wrote concerning them, and their variously coloured appearance, when made with white light, called Grimaldi's fringes. They are produced by the *interference* of the rays bent into the shadow on one side of the body, with the rays bent into the shadow of the other. We have, therefore, the case of two portions of light producing darkness. This announcement appears improbable and paradoxical; it, indeed, appears to contradict all our preconceived notions of the characteristic property of light, which is to illumine and not to darken the body it falls upon. The fact, however, is undeniable, and is

very directly proved by the following exceedingly simple experiment.

Let the solar light be admitted into a dark chamber, by two small pin-holes, placed at such a distance from each other that the conical pencils do not intermix till a convenient distance, at which they may be received upon a white screen. It will then be observed, that at some points of the illuminated space there is partial darkness. But if one of the openings be closed, so that the light is not intermixed in the illumined space, the partial darkness will vanish, and parts of the circle will have become brighter by this loss of light. If red, yellow, or blue light be admitted, the intermixture of the pencils will produce bands which are alternately bright and dark, exactly like the bands already described; and if one of the apertures be closed, the bands will disappear. These are direct and distinct facts.

We may, however, still simplify the experiments. Thus, if a disc, perforated with a pin-hole in the centre, be held in a strong diverging beam of solar light, and the shadow of the disc be received upon a white card, instead of having a luminous point opposite to the hole, there will be observed a dark spot in the shadow corresponding to it. This is explained upon the principle of interference; for we can suppose that the light which passes directly through the aperture will interfere with that which passes more obliquely, and thus, neutralize each other's illuminating power.

The inflection of light is also proved by a similar experiment to this last; for if we employ a very small disc of metal—not perforated—we shall observe that its shadow is brighter at the centre than at any other part. This curious fact is best observed by cementing the disc upon a slip of glass, and holding it in a strong beam of diverging light. Or, instead of the metallic disc, a drop of thick black ink may be allowed to dry upon the glass, so as to form a circular spot about the tenth of an inch in diameter. The shadow formed resembles precisely a circular disc, which becomes more and more opaque from the centre towards the circumference. The explanation given by professor Powell, to whom we are indebted for the experiment, is, that the rays passing by the circumference are inflected, and meet, after traversing equal paths, without crossing each other. *A priori* we might have expected the centre of the shadow to be the darkest point—yet the fact was foretold previous to the experiment being tried.

The phenomena of the interference of light are exceedingly common and familiar. Thus, the irridescence observed upon the surface of *mother-of-pearl,* the brilliant tints of soap-bubbles, the splendid and variable colours of the plumage of many birds, the gorgeous colouring of numerous shells, and fishes, and the lustre and colouring of many minerals, are all examples of the interference of light, and are all comprehended in the same explanation. Take one general instance—the vivid colours presented by thin plates of transparent substances, as glass, and mica. The thinnest films of these substances both transmit and reflect light; but they reflect from both surfaces, and, thus, the light reflected from the first surface interfering with that reflected from the second, produces the chromatic phenomena observed. The irridescence of mother-of-pearl is strictly referrible to the fine parallel lines formed upon its texture; these lines reflect highly, and by interference of the rays passing from their opposite sides—the play of colours so much admired is produced. The fine and close plumage of some birds has the same effect, arising from its fibrous structure; while the colours of shells, and fishes, are the effects of a finely laminated structure. These phenomena are indeed easily seen to depend upon the same cause which gives colour to the soap-bubble, and to a film of oil upon the surface of a basin of water that has been darkened with ink.

Even thin plates of air give rise to all the phenomena of colouring observed in the soap-bubble. To show this experimentally, it is only necessary to press a lens, which is slightly convex, upon a plate of glass, and hold it in the light so that rays reflected from it may pass to the eye. At the point of apparent contact of the lens and the glass a black spot is visible; this is surrounded by a great number of rings of different colours, but each series of tints consists of fewer colours as these recede from the centre. When achromatic light is employed—as light from a spirit-lamp with a salted wick—the rings are alternately bright and dark, and are exceedingly numerous and distinct. The dark rings are formed by the transmitted light, and the bright rings by the reflected light; for if the glasses be held between the eye and the light, the *centre* will appear *bright,* and surrounded by a dark ring next a bright one, and so on alternately. It is thus evident, that the circle which appears black by reflected light is that which appears bright by transmitted light, and conversely. It may also be observed, when solar light is used, that the colours formed by transmission are *complementary* to those formed by reflection—that is, each ring possesses that colour, which, by mixing with the tint of the corresponding reflected ring, would produce white light.

These phenomena may be exhibited by merely placing two plates of window glass, about four inches square, together, and pressing them in the centre by a steel or other metallic point. If the surfaces be not exact planes, which they unfrequently are, the rings will arrange themselves irregularly, but always with great beauty around the point where the pressure is applied. The two glasses may also be fixed together by a little wax, so that two of their edges shall be about a tenth of an inch apart, while the opposite edges are in contact, thereby forming the sides of a very acute angle; and if, with this arrangement, a lighted candle be viewed through the double plate, numerous reflected images of it will appear. The first of them is crossed by a series of beautiful bands. They are all increased in breadth by diminishing the inclination of the plates, and are very obviously produced by the interference of the light reflected from the surfaces of the glass-plates.

In the most superficial account of these facts, it is impossible to avoid allusion to the two rival theories of light. It is readily admitted that, wherever there is light there is motion. The time which light takes to come from the satellites of Jupiter to us is sufficient proof of this fact. Now, we are acquainted with two kinds of motion—that of translation, and that of vibration. It is on these kinds of motion that the two opinions, respecting light, differ; one holds that the motion of light is a motion of translation, and that the luminous substance is emitted from the luminary in all directions; whereas those who hold the hypothesis of vibration maintain, that the luminous influence is propagated by undulations of an ethereal medium which pervades all space, and which suffers little displacement. In this case the luminous substance is supposed to have an existence independent of the luminous body, just as air has an existence independent of the sonorous body; and that this substance, at rest, would not constitute light any more than air at rest constitutes sound.

It will readily appear that this opinion is supported by the facts described, whereas the whole phenomena of interference is at variance with the hypothesis of emission—for it is impossible to suppose two particles, having the same velocity, and moving nearly in the same direction, to have their velocities absolutely destroyed, on meeting with each other. The supposition is mechanically absurd. But, it is not difficult to see, that two undulations may so act upon each other that both may be obliterated. We have, indeed, examples of interference occurring in the undulations produced in liquids, and in the musical vibrations produced by two strings, as facts of experience, pointing directly to a physical explanation. When a system of waves on water interfere with one another under certain conditions, the force of the one is added to the force of the other, and the height of the waves is doubled; but, when they interfere at intermediate intervals, the rise of one corresponds to the fall of the other, and both are obliterated. Again, that kind of cessation and increase of sound, which is produced by two musical notes nearly in unison, and which is known by the name of *beats,* presents us with a striking analogy to the alternate luminous and black fringes arising from the interference of light. Two sets of sonorous vibrations of equal intensity, and encountering each other in opposite directions, will, in like manner, check each other, and produce silence by their conflict. These facts, extended to luminous waves, seem to go far towards a physical explanation of light, and, taken in connexion with the phenomena described, we are justified, in concluding, that if the hypothesis of undulations be false, that of emission cannot be true.

It is, however, proper to observe, that it has been objected to the undulatory hypothesis, that "if true light ought to bend round opaque objects, in the same manner as waves of water find their way round fixed obstacles, and be communicated through curved tubes like sound, and consequently no true shadow ought to exist." These are not unanswerable objections, for we know

that sonorous vibrations do not bend round obstacles with facility, and that an acoustic shadow does really exist. Sound is readily transmitted through curved tubes, while light is completely stopped—for no person can see through a bent brass pipe. But, it must be borne in mind, that while the sides of the tube are sufficiently smooth and elastic to reflect sound, and to assume sonorous vibrations, they are infinitely too rough, and too inelastic, to reflect light, and to assume undulatory movements sufficiently rapid to produce light. The material of the tube, therefore, stifles and checks any undulations which may strike against it, just as any other opaque substance does. And, moreover, we have seen that light does pass round opaque bodies to a certain extent, producing the phenomena of inflection and diffraction, described at the beginning of this chapter.

# MECHANICS.

## PART II.—ELEMENTS OF MACHINERY.

### CHAPTER I.

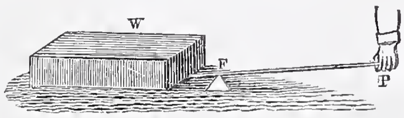
#### THE LEVER.

To produce mechanical effects it is rarely convenient to apply directly our available force, meaning by *mechanical effect*, moving a body of a certain weight through a certain space. The assistance of machinery is required. In fact, the essential idea of machinery is, that it renders force available for effecting certain practical ends. Machines prepare, as it were, the raw material of force supplied to us from natural sources. It is transmitted and modified by certain combinations of the elements of machinery, and is given off at last in a condition suitable for producing the desired mechanical effect. We do not *create* force; the end of machinery is just to transmit it, and diffuse or concentrate it in one or more points of action. The various diffused or concentrated forces, then, being added together, will just amount to the original available force.

All machinery, when analyzed, will be found to consist of a combination of six simple machines or elements, commonly called mechanical powers. This term is not correctly applied to these elements. They are not *powers*, or, in other words, sources of force; they simply transmit and diffuse or concentrate forces. These six elements are,—the *lever*, the *pulley*, the *wheel and axle*, the *inclined plane*, the *wedge*, and the *screw*. To understand, therefore, the nature of any machine, a correct idea of these elements is requisite. The lever, in particular, will now be explained.

A lever is an inflexible rod, by the application of which one force may balance or overcome another. These forces are termed, respectively, the *power* and the *resistance* or *weight*, not from any difference in the action of the forces, but with reference merely to the intention with which the machine is used; and, indeed the same terms are used about all the other mechanical elements. In applying the rod to operate upon any resistance it must rest upon a centre prop or *fulcrum*, somewhere along its length, upon which it turns in the performance of its work. Thus, there are three points in every lever to be regarded in examining its action, namely, the two points of application of the power and the weight, and the point resting on the fulcrum.

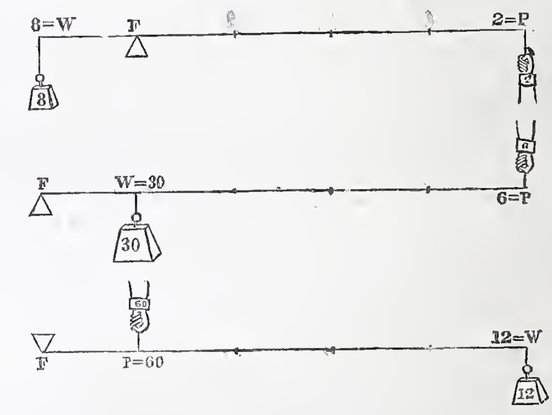
The fulcrum may lie either between the power and the weight, or outside both. This circumstance gives three varieties of levers:—First, when the fulcrum lies between the power and the resistance; second, when the fulcrum lies outside the resistance; and, third, when it lies outside the power. The first of these cases is familiarly illustrated in the operation of raising heavy stones, as in the figure where W P is a straight iron lever, and the power of a hand is applied at P, while the resistance is offered by the stone at W, all working on the fixed centre F, between P and W. Other instances of the same kind are the common weighing-beam, to which we shall afterwards refer, and the poker, when used in stirring a fire; in which case the burning fuel is the resistance, the ribs of the grate are the fulcrum, and the pressure of the hand at the extremity is the power. A pair of scissors also, is an example, when cutting any resisting material.




The second kind of lever, in which the fulcrum is next the weight outside, is exemplified by a man holding a wheelbarrow. The axle of the wheel is the fulcrum, the load on the barrow is the weight to be raised, and the force of the hands at the poles is the power acting at the other extremity of the barrow, which is thus essentially a lever. The starting handle of a locomotive engine is another instance, where the rod that communicates motion to the valve gear is jointed to the handle between the pivot, which is below, and the upper end of the handle. Again, the blowing of a pair of bellows affords another example. The leather hinge at the root of the nozzle is the fulcrum, the air within and without offers the resistance to opening and shutting, and the effort of the hand at the other end to overcome the resistance, is the power employed. Two men carrying a load between them on a pole is a fourth example of levers of the second kind; each man's shoulder being a fulcrum in respect to the shoulder of the other, which is relatively the source of the power, while the load between them is weight sustained upon the pole, which is the lever.

The third kind of lever, or that where the fulcrum is next outside the power, is illustrated in opening and shutting a gate by applying the hand near the hinges; for here the hinges are the fulcrum, the body of the gate is the resistance to be moved, and the force of the hand is the power. The lever of the third kind is also very much employed in the mechanical movements existing in the bodies of animals. These examples will afterwards be alluded to.

The use of a lever, then, is to overcome one force by the action of another; and there are three points in every lever to which forces are applied, which must be in equilibrium when the power is just sufficient to balance the resistance, leaving out of notice the weight of the lever itself. In the accompanying figures the three varieties of levers are represented in their




simplest form. They are straight lines on which three forces act perpendicularly, namely, the power, the weight, and the reaction of the fulcrum. In each case there is a system of three parallel forces in equilibrium. On referring to Article 25, page 300, it is stated, that of three parallel forces, acting on a straight line, which the levers may be considered to be, two of them must be opposed to the third which must act between them, and the middle force is always equal to the sum of the two outside forces. From this the amount of resistance offered by the fulcrum may always be ascertained. Moreover, the principle of the equality of moments must always obtain among them. Take, then, in each case, the fulcrum F as the point from which the moments of the forces are to be measured. The moment about this point, therefore, of the resistance of the fulcrum, in each case, will be nothing, for the distance of this force from the point F, is, of course, nothing. But, although one of the forces in each case has thus no moment, the equality of the moments of the other two must, nevertheless, obtain. In fact, the moment of the force P at the distance P F, is equal to that of the force W at the distance W F; that is, P multiplied by P F is equal to W multiplied by W F. In the first of the figures, let the forces at W and P be

represented respectively by 8 lbs. and 2 lbs. Then taking W F the distance of W from F for the unit of measure, say one foot, we have 8 multiplied by 1 equal to 8, which is the moment of the force W; and, therefore, the units of measure, or number of feet, in the distance P F of the point P must be such, as, when multiplied by 2, the pressure in lbs. at P, the result (or the moment) of this pressure will also be 8. It is evident, then, that 4 is the number, for 2 multiplied by 4 is equal to 8, showing that P F is 4 times as long as W F. Again, in the second figure, the force W acts with a pressure, say of 30 lbs. at the distance from F of one foot, so that its moment is 30 multiplied by 1 or 30. Now the force P operates at a distance of 5 feet, showing that the magnitude of P in lbs., when multiplied by 5, must also have 30 for its moment. Thus, it appears that 6 lbs. must be the force of P, for 6 multiplied by 5 is equal to 30, which is the moment of P and W. Again, in the third figure, the weight W is at 5 times the distance from the fulcrum F that the power P is, which is the reverse of the last case. If therefore, W be 12 lbs., its moment is 12 multiplied by 5, or 60. The force P, therefore, when multiplied by its distance P F, will also have 60 for its moment; that is, it must be 60 lbs., for its distance is one unit of measure, and 60 multiplied by 1 is 60, which is also the moment of W.

We have observed a certain relation between the magnitudes of the opposing force, and their distances from the fulcrum, namely, that, in every case, the power, multiplied by its distance from the fulcrum, is equal to the weight multiplied by its distance from the same point. From this, simple rules may be deduced for calculation.

To know the power to be applied at a certain distance from the fulcrum, to overcome a resistance acting also at a certain distance, multiply the resistance by its distance from the fulcrum, which gives its moment, and divide the product by the distance given, the quotient will be the power; it being observed that the distances and the forces be each expressed in the same unit of measure. For example, a weight of 10 cwt., at 3 inches from the fulcrum, is to be balanced by a force at the distance of 10 feet. Now 10 feet is equal to 120 inches, and the moment of 10 cwt. is $10 \times 3 = 30$. Divide this by 120 we have $\frac{1}{4}$ cwt., which is 28 lbs. for the power required.

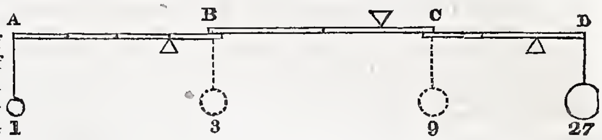
Again, to know the distance at which a given force ought to be applied to balance a given weight at a certain distance, we must, in like manner, multiply the weight by its distance, as before, and divide by the given power. 10 cwt., for example, at 3 inches distance is to be balanced by a force of 28 lbs; to find the distance of this weight, 10 cwt. is equal to 1120 lbs., this multiplied by 3 gives 3360, which, divided by 28, gives 120 inches or 10 feet.

While the erroneous opinion prevailed that machinery *increased* power, instead of merely *accommodating* forces to certain purposes, the third class of lever, where a great force acting at a short distance is made to gain great extent of motion, was regarded by many as a most unprofitable contrivance, and was called the *losing lever*.

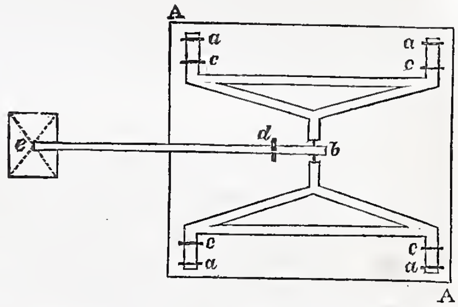
The weighing beam and scales are the most common application of the lever with equal arms, and the steel-yard with unequal arms. When the power and the weight are at equal distances from the fulcrum, they must be equal to one another to induce equilibrium; and thus a means of testing the weights of quantities is afforded. If the two arms be not of perfectly equal lengths, a small weight at the end of the longer will balance a greater weight at the end of the shorter. An excess of half an inch in the length of a beam arm to which grocery is hung, and which should be eight inches long, would cheat the purchaser of very nearly an ounce out of every pound. But, for the same reason of the inequality of the arms, the fraud could be detected by transposing the weights and goods into the opposite scales, when the merchandise would now show a double deficiency.

The steel-yard has a long and short arm, from the latter of which a scale is hung, and into it the goods to be weighed are placed. On the longer arm a sliding weight is hung, which, by being shifted to various distances from the fulcrum, balance articles of various weights in the scale.

The rules for the determination of the conditions of equilibrium in the simple lever, are also available for the same purpose in a combination of levers. If the short end of a lever A B, which makes 1 balance 3, be applied to the long arm of another, B C, which does the same, then 1 lb. at the end of the long arm




of the first will balance 3 times 3, or 9 lbs., at the short end of the second; and, still farther, by applying the second to a third lever, C D, of the same proportions, 3 times 9, or 27 lbs., at the short end of the lever will yet be balanced by the 1 lb. But such a combination of levers could be practically useful only where the end A required to move through but a small space up or down; for it is easy to see that the lever A B could not move much without slipping past the end of the second one. The cart weighing-machine, of which the annexed is a sketch in plan, presents an elegant combination of levers, by which the proportion of the power is to the weight, when balanced, generally as 1 to 28, or 4 lbs. to the cwt. A A is a square frame fitted for the reception of the apparatus. At the four corners are fixed four fulcra, *a*, *a*, *a a*, on which the triangular levers, *a a b*, *a a b*, rest by their extremities. There are thus two fulcra to each lever, which may in fact be looked upon as two levers combined into one at *b*. At the points *c c c c*, 5 inches from *a* and *c*, the top-plate, which receives the load to be weighed, rests by four legs. Thus, the pressure of the load is communicated by the four corners to the extremities *b b* of the levers, which are 20 inches perpendicular distance from *a a* and *c*. These are suspended by links to a steel centre fixed at *b* in the lever *b d e*. The distance *b d* from the fulcrum is 6 inches, and *d e* is 42 inches, the scale for the weight being hung at *e*. To calculate, then, the proportion of the power to the weight to be balanced, the levers *a a b* are of the second class, the weight being between the fulcrum and the power; and the respective distances of the weight and the power from the fulcrum are 5 and 20, or as 1 to 4; so that the balancing effort at *b* is one-fourth of the whole load. Again, the lever *b d e* is one of the first class; for the fulcrum *a* is in the middle, and its distances from the points *b* and *e* are 6 and 42 inches, or in the proportion of 1 to 7, showing that a force at *b* will be balanced by one-seventh of itself at *e*. Now the force at *b*, as we have already found, is one-fourth of the whole load; so that the force at *e* necessary to balance it will be one-seventh of one-fourth of the load or $\frac{1}{28}$. Thus, the machine requires 4 lbs. on the scale for every cwt. on the table. The weight of the moving parts of the machine is previously balanced by counter-weights.




## ON CHLORIMETRY, AND ON A NEW MODE OF TESTING WEAK SOLUTIONS OF BLEACHING POWDER.

CHLORIDE OF LIME is one of those substances whose value cannot be judged of from its external appearance, and which is always mixed with a certain quantity of foreign matter. An experiment is therefore necessary to test it, and an easy method of performing such an experiment has always been a desideratum with those who manufacture or employ it.

I propose to give an account of some of the methods which have been hitherto in use for ascertaining the strength of mixtures containing chlorine, and then to describe one I have myself employed for some time.

The oldest method is that of Decroizilles, where the amount

of chlorine in a solution is measured by the quantity of indigo which that solution is capable of discolouring. Welter made use of it, in his researches on the nature of chloride of lime, in 1818, and considered it susceptible of great accuracy, by attending to certain precautions which he pointed out. In 1824, Gay Lussac published a set of experiments on this art, to which he gave the name of Chlorimetry. He also adopted the indigo test, and made every arrangement for accuracy which the method would permit. A volume of chlorine was taken for unity; or, which is the same thing, a volume of liquid which had absorbed its bulk of chlorine. This is formed by filling a bottle with chlorine gas, inverting it in a vessel containing cream of lime, and withdrawing the stopper. The chlorine is gradually absorbed, and its place taken by the lime water,—which has then become a solution of bleaching powder containing its own volume of chlorine gas.

To form the indigo solution, one part of the best indigo of commerce is dissolved in nine of sulphuric acid, and diluted with water to such an extent, that one measure of the chlorine solution discolours ten measures of it. When the two solutions are mixed together, the chlorine is set free by the sulphuric acid in which the indigo is dissolved, and the indigo is immediately destroyed. The solution of indigo is called "proof tincture," and the quantity of it, which an unknown solution of bleaching powder is capable of discolouring, indicates the bulk of chlorine gas which it contains.

Much of the accuracy of this method depends upon the way in which the two solutions are mixed. Thus, by pouring the chlorine slowly upon the indigo, much more of it is destroyed than when the indigo solution is poured into that containing the chlorine. A great many trials satisfied M. Gay Lussac, that the best process is to mix the two solutions rapidly together. But then several preliminary trials are necessary to ascertain pretty nearly how much should be employed.

Three years after, in 1827, M. Morin, of Geneva, published experiments on chloride of lime, and discussed the merits of the indigo test. He found it impossible to have the circumstances always so much alike as to produce anything like uniform results with it. In 1831, M. Marozeau corroborated the view taken by Morin, and added, (what every one who has repeated the process must have noticed,) that it is very difficult to observe the exact point at which the indigo is wholly destroyed, from the want of a distinct line between the brown after complete discoloration, and the slightly greenish tint, which M. Gay Lussac indicates as the point most desirable to stop at.

Each of these chemists proposes a substitute for the chlorimeter of Gay Lussac. M. Morin would employ muriate of manganese instead of indigo; but he gives no details of his process, and it would seem to be both tedious and uncertain. The process of M. Marozeau is founded on the property which chlorine possesses of converting calomel, an insoluble substance, into corrosive sublimate, which is abundantly soluble, and which contains twice as much chlorine. Proto-nitrate of mercury is formed by boiling nitric acid and water with an excess of mercury. It is afterwards diluted and set aside, when subnitrate precipitates. The salt remaining in solution, after being made of a strength to correspond with a volume of dry chlorine gas, is the proof liquor. To ascertain by this means the strength of any solution containing chlorine, we take a measure of nitrate of mercury, add muriatic acid to convert it into calomel, and then the chloride slowly. The quantity necessary to make the precipitate entirely redissolve is inversely as the chlorine which it contains.

At last, M. Gay Lussac himself, in the year 1835, announced that, after three years' experience of a new process, he had abandoned the method with indigo. His objections to it are partly those already stated, and partly the change which readily takes places on the indigo solution when preserved for any length of time. By the new method, any one of three substances may be employed with the same apparatus, and with nearly equal advantage—

1. Arsenious acid.
2. Ferrocyanide of potassium.
3. Protonitrate of mercury.

M. Gay Lussac prefers, however, the arsenious acid, from the precision of its indications. He retains the same basis of measurement as for the test with indigo alone—that is, he takes for unity the discolouring power of one volume of chlorine dissolved in an equal volume of water. That is divided into 100 equal parts. The arsenious solution is prepared of a strength just sufficient to destroy an equal volume of chlorine gas, or of the chlorine solution. If we take a constant quantity of the unknown solution of chlorine, say 10 cubic centimeters, and pour into it the arsenious solution till the chlorine is gone, the force of the chlorine solution will be in proportion to the quantity of arsenic employed. If the 100 measures of solution of chloride have taken 100 measures of the arsenious solution, then it has the strength of 100, and it contains its own volume of chlorine gas. If only 80, then it is called of the strength of 80 degrees, and it contains $\frac{80}{100}$ of its bulk of chlorine gas. But this mode of operating would not give good results; for the muriatic acid which is employed to dissolve the arsenic, and without which the action of the chlorine would be incomplete, disengages the chlorine from its fixed combination with lime faster than it has arsenic to act upon, and thus a portion escapes into the air. The solution of bleaching powder must therefore be poured by degrees into the arsenious solution, and as the strength of the chlorine solution is then inversely as the quantity employed, a calculation is necessary, or a table has previously to be prepared, by the inspection of which, the result may at once be observed. The point of saturation of the arsenic is indicated by a blue tinge, which is given to the arsenious solution by indigo. This substance is not affected by chlorine so long as any arsenious acid is left, after which a single drop of chlorine solution causes it to disappear.

In employing the prussiate of potash, the instruments and manipulation are the same. Its solution is made of the same strength as the arsenious solution—that is, that it should saturate an equal volume of the normal solution of chlorine. Prussiate of potash has a very slight action upon chloride of lime, but if previously rendered acid, it is immediately changed by it, and becomes yellow.

The prussic acid test has long been employed by my friend, Mr John Mercer, of Oakenshaw, near Manchester. His test, to mark the point at which the prussic acid becomes saturated, is the red oxide of iron. A bit of calico dyed buff with iron, is touched with the solution after each addition of the chlorine, and as soon as it ceases to become blue, enough of the chlorine has been added.

Gay Lussac's third process is that of M. Marozeau with nitrate of mercury already described. It appears that Balland de Toul first recommended this method, two years before the publication of M. Marozeau.

Mr John Dalton pointed out a process in 1813, which gives very good results; and, arranged as it has been by Mr Graham, it seems to be the best and most easily executed of all the tests of bleaching powder. Mr Graham directs that a few ounces of good crystals of protosulphate of iron should be pounded, and dried between folds of cloth. 78 grains of crystals so dried, are equivalent to 10 grains of chlorine. The 78 grains are to be dissolved in 2 ounces of water, and acidulated with a few drops of muriatic acid. 50 grains of the bleaching powder to be examined, are dissolved in about 2 ounces of tepid water, by rubbing them together in a mortar. The whole is then poured into a graduated tube, called an alkalimeter, divided into 100 parts, and filled up with water to 0 on the scale. The solution of bleaching powder being thus made up to 100 measures, is poured into the solution of iron until it is wholly saturated. The point of saturation is discovered by means of red prussiate of potash, which gives a blue precipitate with protoxide of iron only, and not with salts of the peroxide. A white stoneware plate is spotted over with small drops of the red prussiate; and, as soon as the iron solution ceases to produce a blue, when a drop of it is applied to one of these spots, no more protosulphate remains. Suppose 72 measures of the bleaching liquor to have saturated the 78 grains of green copperas, then these 72 measures contained 10 grains of chlorine, which is equal to 13·89 grains in the 50 grains of chloride of lime, or 27·78 grains of chlorine in 100 grains. The calculation is simplified by at once dividing 2000 by the number of measures required, thus:—

$$\frac{2000}{72} = 27{\cdot}78$$

On repeating the experiment in the way prescribed by Mr. Graham, I find it of importance to mix the two solutions in a phial. It is corked up and well shaken after each addition of the bleaching liquid. By this means the chlorine, a small quan-

tity of which is set free after every addition, is prevented from escaping, and a much more perfect agitation and mixture is attained than by the use of the spatula. By the same means the employment of the mortar and alkalimeter may be dispensed with. If the 78 grains of the sulphate of iron be put, along with some muriatic acid, into a wide-mouthed 4 oz. phial, half filled with water, the bleaching powder may be added dry, and the result obtained by weighing the residue.

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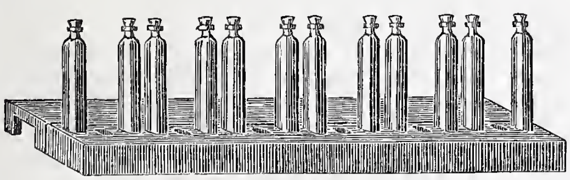
Chlorimetry requires to be practised by the bleacher for two purposes—First, he has to learn the commercial value of the bleaching powder which he purchases; and with that view he can scarcely desire anything better than the method either by arsenious acid, or green copperas. But the more important, because the hourly testing of his bleaching liquor, and that on which the safety of his goods depends, is the ascertaining the strength of the weak solutions in which the goods have to be immersed. If the solution is too strong, the fabric is apt to be injured. If too weak, parts of the goods remain brown, and the operation must be repeated. The range within which cotton is safe in this process is not very wide. A solution standing 1° on Twaddell's hydrometer, (spec. grav. 1·005) is not more than safe for such goods, while that of half a degree is scarcely sufficient for the first operation of stout cloth, unless it is packed more loosely than usual. When the vessel is first set with fresh solution of bleaching powder, there is little difficulty, if the character of the powder be known; but when the goods are retired from the steeping vessels, they leave a portion of bleaching liquor behind, unexhausted, which must be taken into account in restoring the liquor to the requisite strength for the next parcel. The chlorimeter must, therefore, be applied every time that fresh goods are put into the liquid. It must consequently be intrusted to persons who may not be expert either in figures or in chemical manipulation. Hence all the processes I have described are too delicate and tedious.

I introduced another into our establishment some years ago, which has been in regular use ever since, and by which the testing is performed in an instant. It depends on the depth of colour of the peracetate of iron. A solution is formed of proto-chloride of iron, by dissolving cast-iron turnings in muriatic acid, of half the usual strength. To ensure perfect saturation, a large excess of iron is kept for some time in contact with the solution at the heat of boiling water. One measure of this solution, at 40° Twaddell, (spec. grav. 1·200) is mixed with one of acetic acid, such as Turnbull and Co. of Glasgow sell at 8*s*. a gallon. That forms the proof solution. If mixed with six or eight parts of water it is quite colourless; but chloride of lime occasions with it the production of peracetate of iron, which has a peculiarly intense red colour.

A set of phials is procured, 12 in number, all of the same diameter. A quantity of the proof solution, equal to $\frac{1}{5}$th of their



capacity, is put into each, and then they are filled up with bleaching liquor of various strengths, the first at $\frac{1}{12}$th of a degree of Twaddell, the second, $\frac{2}{12}$ths, the third, $\frac{3}{12}$ths, and so on up to $\frac{12}{12}$ths, or 1 degree. They are then well corked up, and ranged together, two and two, in a piece of wood, in holes drilled to suit them. We have thus a series of phials, showing the shades of colour which those various solutions are capable of producing. To ascertain the strength of an unknown and partially exhausted bleaching liquor, the proof solution of iron is put into a phial similar to those in the instrument, up to a certain mark, $\frac{1}{5}$th of the whole. The phial is then filled up with the unknown bleaching liquor, shaken, and placed beside that one in the instrument, which most resembles it. The number of that phial is its strength in 12ths of a degree of the hydrometer; and, by inspecting the annexed table, we find at once how much of a solution of bleaching powder, which is always kept in stock, at a uniform strength of 6 degrees, is necessary to raise the whole of the liquor in the steeping vessel to the desired strength.



The instrument is formed of long 2 ounce phials cast in a mould; those of blown glass not being of uniform diameter. The outside, which alone is rough, is polished by grinding, and in this state they can easily be procured at 4*s*. 6*d*. a dozen. They are placed two and two, so that the bottle containing the liquid to be examined may be set by the side of any one in the series, and the colour compared by looking through the liquid upon a broad piece of white paper stretched upon a board behind the instrument.

To explain the table, it is necessary to state that the steeping vessels we employ contain, at the proper height for receiving goods, 1440 gallons, or 288 measures of 5 gallons each,—a measure being the quantity easily carried at a time. In the following table, 0 represents water, and the numbers 1, 2, 3, &c., are the strength of the liquor already in the vessel in 12ths of a degree of Twaddell, as ascertained by the chlorimeter. If the vessel has to be set anew, we see by the first table that 32 measures of liquor at 6° must be added to (256 measures of) water to produce 288 measures of liquor at $\frac{3}{12}$ths of a degree. But if the liquor already in the vessel is found by the chlorimeter to produce a colour equal to the 2d phial, then 24 measures only are necessary, and so on.

| To stand $\frac{8}{12}$° | | | To stand $\frac{6}{12}$° | | |
|---|---|---|---|---|---|
| 0 requires | 32 | measures. | 0 requires | 24 | measures. |
| 1 — | 28 | — | 1 — | 20 | — |
| 2 — | 24 | — | 2 — | 16 | — |
| 3 — | 20 | — | 3 — | 12 | — |
| 4 — | 16 | — | 4 — | 8 | — |
| 5 — | 12 | — | 5 — | 4 | — |
| 6 — | 8 | — | | | |
| 7 — | 4 | — | | | |

| To stand $\frac{4}{12}$° | | | To stand $\frac{3}{12}$° | | |
|---|---|---|---|---|---|
| 0 requires | 16 | measures. | 0 requires | 12 | measures. |
| 1 — | 12 | — | 1 — | 8 | — |
| 2 — | 8 | — | 2 — | 4 | — |
| 3 — | 4 | — | | | |

Let us see what takes place on mixing chloride of lime with protomuriate of iron. On the old view of the constitution of bleaching powder—that it is a combination of chlorine and lime, we have

$$\left.\begin{matrix} 3\,(CaO,\,Cl) \\ 6\;\;FeCl \end{matrix}\right\}\text{ becoming }\left\{\begin{matrix} 3\;CaCl \\ 2\;Fe_2Cl_3 \\ \;\;Fe_2O_3 \end{matrix}\right.$$

the peroxide of iron forming peracetate with the acetic acid which is present. Or, supposing with Balard that when two atoms of chlorine unite with two atoms of lime, the product is $CaCl + CaO,\ ClO$, we have this formula:—

$$\left.\begin{matrix} 3\;\;CaCl \\ 3\,(CaO,\,ClO) \\ 12\;\;FeCl \end{matrix}\right\}\text{ becoming }\left\{\begin{matrix} 6\;CaCl \\ 4\;Fe_2Cl_3 \\ 2\;Fe_2O_3 \end{matrix}\right.$$

Here one-third only of the iron goes to form the deep coloured peracetate, while the whole might be employed for that purpose, by using protoacetate of protochloride. The latter, however, is preferred, from the greater tendency of the acetate to attract oxygen from the air, and consequently the greater difficulty of preserving it. Even with the chloride it is best to give out small quantities at a time, preserving the stock in well closed bottles.

WALTER CRUM.

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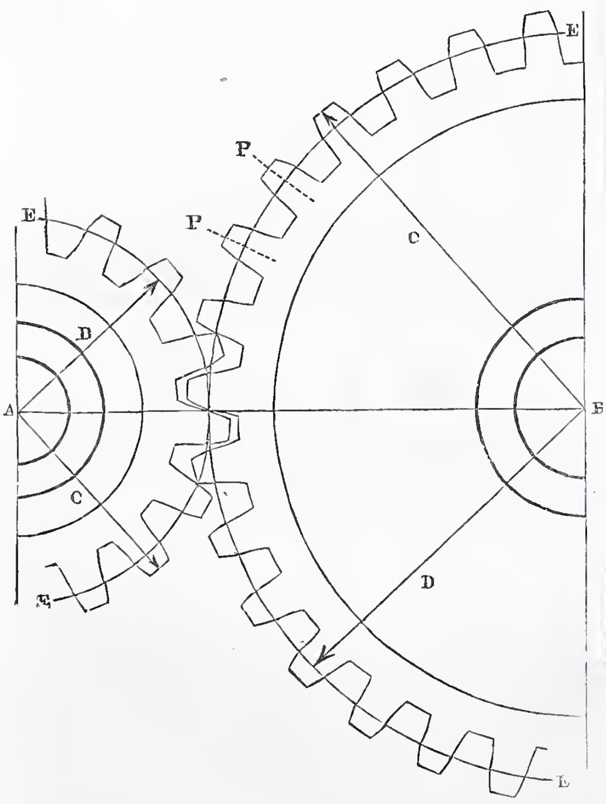
# ON THE TEETH OF WHEELS.

## CHAPTER I.

### ON PITCH.

The proper formation of the teeth of wheels is a subject of great practical importance. It is upon this that much of the accurate and economical working of our modern machinery depends. The investigation of the problem, has, moreover, been a favourite occupation with mathematicians of the highest eminence ; and the conditions involved may now be considered to be very nearly all expressed.

The condition to be fulfilled in the working of a pair of teethed wheels into each other, is the uniform transmission of the power —supposing this to be constant and equal. This implies that the one wheel ought to conduct the other, as if they simply touched in the line joining their centres, as when a pair of corresponding plain circles roll upon each other. The adhesion, indeed, which enables the surface of one plain roller to communicate motion to another, arises from the roughness of the surfaces—the irregular projections of the one indenting themselves between those of the other ; and the contrivance of teeth is merely a complete development of this mode of action, in which the projections have a regular form and arrangement. What is called the *pitch circle* of a toothed wheel is simply the circle whose diameter is equal to that of a cylinder, the rolling action of which would be equivalent to that of a tooth-wheel. It is the limit to which the wheel approaches, as the teeth are indefinitely diminished in size and increased in number, the distance of the axes remaining the same. In conical wheels, again, this circle answers to the base of the frustrum.




In the case of a wheel and pinion, as here shown, the line A B between the centres is called the *line of centres*. The lines D D are the *pitch radii*; C C, the *real radii*; P P, the pitch of the wheel; and the circles E E, are the *pitch lines* or *circles*. A wheel which acts upon another is a *driver* or *leader*; the wheel acted upon is the *droven* or *follower*.

In setting out a wheel the pitch circle is the first line to be drawn : it is the basis of all subsequent calculations. To lay off the requisite number of teeth, it is only necessary to divide its circumference into as many equal parts as there are teeth to be given to the wheel. The length of each of these parts is termed the *pitch* of the teeth, or of the wheel. It evidently contains within itself the exact portion occupied by one complete *tooth and space*—meaning by *space* the opening or gap between each pair of teeth. More shortly, it is the distance between the centres of two contiguous teeth.

Although it is hardly possible to mistake these definitions, it may fix them more permanently upon the mind to point them out more exactly by such a figure as the preceding.

The pitch of a wheel may, of course, be any quantity within certain limits to be hereafter pointed out ; but it has been found convenient to employ only a given number of standard values, instead of using an indefinite number for the pitch. Thus in cast-iron wheels of the larger class, the values most commonly chosen are 1 in., $1\frac{1}{8}$ in., $1\frac{1}{4}$ in., $1\frac{1}{2}$ in., 2 in., $2\frac{1}{2}$ in., 3 in. ; and it very rarely happens that any intermediate values are necessary. Below inch pitch the values $\frac{1}{4}$th, $\frac{3}{8}$ths, $\frac{1}{2}$, $\frac{5}{8}$ths, and $\frac{3}{4}$ths, are generally sufficient. Cast-iron teeth of less than $\frac{1}{4}$th in. pitch are seldom employed ; and for machinery of a less size the wheels are commonly cut in a cutting engine. This system of definite values for the pitch has this advantage, that it limits the number of founders' patterns. Any others, however, may be readily calculated. For if we put P to denote the pitch, D the diameter of the pitch circle, N the number of teeth, and $\pi = 3{\cdot}1416$, or $\frac{22}{7}$ (as is commonly done by millwrights), we shall have the following proportion :

$$N : D :: \pi = \tfrac{22}{7} : P \text{ ; or, simply, } P = \frac{\pi \times D}{N} \quad . \quad . \quad . \quad \text{(I.)}$$

that is, *multiply the diameter by* $\frac{22}{7}$, or 3·1416, *and divide by the number of teeth.*

To take an example—suppose a wheel of four feet diameter, (of pitch circle), to have 66 teeth—what is the pitch ? Here $D = 48$ inches, and $N = 66$ ; and, therefore,

$$P = \frac{\frac{22}{7} \times 48}{66} = \frac{22 \times 48}{7 \times 66} = 2\tfrac{2}{7} \text{ in.}$$

From the general expression given above, we may find any of the quantities P, N, D, when two of them are given : thus,

Having the diameter of the pitch circle, and pitch of the teeth given, to find the number of teeth, the expression is,

$$P : \pi = \tfrac{22}{7} :: D : N \text{, or } N = \frac{\pi \times D}{P} \quad . \quad . \quad . \quad \text{(II.)}$$

that is, *multiply the diameter by* 3·1416, or $\frac{22}{7}$, *and divide by the pitch.*

To take a numerical example—suppose that the diameter of the pitch circle is 3 feet 6 inches (= 42 inches), and the pitch of the teeth 2 inches, then for the number of teeth we have

$$N = \frac{\frac{22}{7} \times 42}{2} = \frac{22 \times 42}{7 \times 2} = 66.$$

Again, having the pitch and number of teeth given, to find the diameter of the pitch circle, we have

$$\pi = \tfrac{22}{7} : P :: N : D \text{, or } D = \frac{N \times P}{\pi} \quad . \quad . \quad . \quad \text{(III.)}$$

that is, *multiply the number of teeth by the pitch, and divide by* 3·1416, or $\frac{22}{7}$.

For a numerical example—suppose that we require a wheel of 120 teeth of $\frac{3}{4}$ths inch pitch—what ought its diameter to be ?—we have

$$D = \frac{120 \times \frac{3}{4}}{\frac{22}{7}} = \frac{120 \times 3 \times 7}{22 \times 4} = 28\tfrac{7}{11} \text{ inches.}$$

Since, in practice, the pitches are few and definite—the last two rules may be simplified by finding, beforehand, the values of $\frac{P}{\pi}$ and its reciprocal $\frac{\pi}{P}$.

For (II.) may be written $N = \frac{\pi}{P} \times D$.

And (III.) may be written $D = \frac{P}{\pi} \times N$.

The numerical values of these fractional factors, for all the pitches enumerated above, are contained in the following table, for which we are indebted to Professor Willis' valuable treatise on the principles of mechanism.

| Pitch in Inches. | $\frac{\pi}{P}$ | $\frac{P}{\pi}$ |
|---|---|---|
| 3 | 1·0472 | ·9548 |
| $2\frac{1}{2}$ | 1·2566 | ·7958 |
| 2 | 1·5708 | ·6366 |
| $1\frac{1}{2}$ | 2·0944 | ·4774 |
| $1\frac{1}{4}$ | 2·5132 | ·3978 |
| $1\frac{1}{8}$ | 2·7924 | ·3580 |
| 1 | 3·1416 | ·3182 |
| $\frac{3}{4}$ | 4·1888 | ·2386 |
| $\frac{5}{8}$ | 5·0265 | ·1988 |
| $\frac{1}{2}$ | 6·2831 | ·1590 |
| $\frac{3}{8}$ | 8·3776 | ·1194 |
| $\frac{1}{4}$ | 12·5664 | ·0796 |

From this table the number of teeth may be readily found for any given diameter, and conversely the diameter may be found for any given number of teeth—provided the pitch be one of those in the table.

Thus, to find the number of teeth, multiply the diameter by the value of $\frac{\pi}{P}$ corresponding to the given pitch.

And, to find the diameter, multiply the number of teeth by the value of $\frac{P}{\pi}$ corresponding to the given pitch.

As an example—a wheel of five feet diameter, and 2 inches pitch, is given to determine the number of teeth. Here the value of $\frac{\pi}{P}$ corresponding to the pitch, is 1·5708, which, multiplied by the number of inches in five feet, gives 94·248, that is $94\frac{1}{4}$; but, as fractions are not admissible, we take the nearest whole number which is 94. To correct the error of the quarter teeth, the pitch may be taken *very slightly* greater than two inches, or the diameter of the pitch circle may be taken slightly less than five feet. To show what must be the amount of this correction, let us suppose a wheel of 94 teeth of two inches pitch, given to find the diameter. Corresponding to two inches pitch, the value of $\frac{P}{\pi}$ is ·6366, which, multiplied by 94, gives 59.84 inches as the diameter—that is, about $\frac{1}{6}$th of an inch less than five feet.

Since $\frac{P}{\pi}=\frac{D}{N}$ we may also use the table in finding the pitch. For example, supposing it required to find the pitch of a wheel 16 inches diameter, with 200 teeth. Here $\frac{D}{N}=\frac{16}{200}=\cdot 08=\frac{P}{\pi}$.

Now this value of $\frac{P}{\pi}$ differs exceedingly little from ·0796 which corresponds to $\frac{1}{4}$th inch pitch.

Questions of this kind may appear trivially simple, and below the notice of the mathematical reader; but, it is to be borne in mind, that they are of very frequent occurrence in the workshop where every man is not a mathematician.

By way of simplifying the expression of the relations between the size of teeth, their number, and the diameter of the pitch circle—a different mode of division, from that explained, has been adopted in Manchester for small machinery. It is thus explained by Professor Willis.

Suppose the diameter of the pitch circle to be divided into as many equal parts as the wheel has teeth; and let one of those parts be taken for a modulus instead of the pitch hitherto employed; and, finally, let the few necessary values be assigned to it in simple fractions of the inch. Call this new modulus the *diametral pitch* of the wheel to distinguish it from the common pitch, which may be named the *circular pitch*. If now M denote the diametral pitch, then $D \div N = M$, and as M is a simple fraction of an inch, let $M=\frac{1}{m}=\frac{D}{N}$, from which we get $m \times D = N$, in which N and $m$ are always whole numbers.

The values of $m$ commonly employed are 20, 16, 14, 12, 10, 9, 8, 7, 6, 5, 4, 3; and all wheels being made to correspond to one of the classes indicated by these numbers, the diameter or number of teeth of any required wheel is ascertained with much less calculation than in the common system of circular pitch.

The following table, which is founded upon the practice followed in the works of Messrs Sharp, Roberts, & Co., shows the values of the circular pitch corresponding to the selected values of $m$ given above.

| $m$ | Circular Pitch in Decimals of an Inch. | Circular Pitch in Inches to nearest $\frac{1}{16}$ |
|---|---|---|
| 3 | 1·047 | 1 |
| 4 | ·785 | $\frac{3}{4}$ |
| 5 | ·628 | $\frac{5}{8}$ |
| 6 | ·524 | $\frac{1}{2}$ |
| 7 | ·449 | $\frac{7}{16}$ |
| 8 | ·393 | $\frac{3}{8}$ |
| 9 | ·349 | |
| 10 | ·314 | $\frac{5}{16}$ |
| 12 | ·262 | $\frac{1}{4}$ |
| 14 | ·224 | |
| 16 | ·196 | $\frac{3}{16}$ |
| 20 | ·157 | $\frac{1}{8}$ |

Since $\frac{D}{N}=\frac{P}{\pi}$, and $\frac{D}{N}=M$, therefore $M=\frac{P}{\pi}$, that is, the diametral pitch is the quantity which has been calculated in the third column of the former table. And, indeed, it is easy to see that the scheme differs from the first merely in expressing in small whole numbers the quantity $\frac{\pi}{P}$ instead of P.

A single example will render the mode of using the table plain. Suppose the diameter of the pitch circle of a wheel is 18 inches, and that it is to be cut to a *twelve-pitch*, (that is a pitch in which $m = 12$). All that is necessary is to multiply 18 inches by 12, which gives 216 for the number of teeth in the wheel. The circular pitch P of such a wheel, is accurately ·262 inch, or nearly $\frac{1}{4}$ inch.

Had it been required to find the diameter of a twelve pitch wheel of 216 teeth, we would then have

$$D=\frac{N}{m}=\frac{216}{12}=18 \text{ inches};$$

that is, divide the number of teeth by the given value of $m$.

In very small machinery, as that of clocks and watches, the size of the teeth is denoted by stating the number of them which is contained in the inch of the circumference of the wheel. The word pitch is not used by clock-makers—they employ the term *geometrical circle;* but the rules explained apply to all wheels, however fine the teeth, and however differently the parts may be named.

In fine wheels, which are cut by the cutting engine, it is necessary to calculate the pitch for the purpose of determining the size of the cutter. In entering upon this calculation, it is however as necessary to determine the shape of the cutter as its size—a subject which will be explained when we come to explain the modes of determining the shape of wheel teeth in our next section.

We have enumerated the pitches commonly employed for the wheels of spur gearing, but have stated no reason why one pitch should be preferred, in some cases, to others. Within certain limits, the reason, indeed, appears self-evident; for, since the pitch determines the thickness of the teeth, it must bear some relation to the power to be transmitted. It is, moreover, generally desirable to take the pitch as fine as the condition of strength will admit; but this limit obviously cannot be passed with impunity. The question then involves the investigation of the least quantity of pitch which ought to be employed for the wheels of spur gearing—and, let it be kept in mind, that we suppose the material used to be cast-iron.

In the first place, then, we may suppose it manifest that the teeth of wheels, and wheels themselves, which act with greater force, must be proportionally stronger; and, further, that

in a combination of wheels, the strength must vary from the first movers toward the points of action, so that at every part it may be reciprocal to the velocity of that part. This, however, is only strictly true in the wheels of the same machine; but it becomes a general proposition when our first movers are reduced to the same standard—as the horse power so commonly employed in calculations of this sort.

To see how this is done, let P denote the power of the first mover in the given machine, V its velocity, and $v$ the velocity of the part on which it is necessary to determine the strain. Then we have the proportion

$$v : \mathrm{V} : : \mathrm{P} : \text{strain} = \frac{\mathrm{P} \times \mathrm{V}}{v}$$

Now, taking Desagulier's value of the horse power—that is, 200 pounds moved at the rate of $3\frac{2}{3}$ feet per second, and using H to denote the number of horses' power we have

$$\frac{\mathrm{P} \times \mathrm{V}}{v} = \frac{200\ \mathrm{H} \times 3\frac{2}{3}}{v}, \text{ which may be written } \frac{740\ \mathrm{H}}{v}$$

for the sake of simplicity of expression. This last quantity then expresses the strain at any pitch line of which the velocity is $v$ feet per second when the horse power of the first mover is H—more strictly, when the number of horses' power which *could* perform the work is H.

Now, supposing with Tredgold that a square inch of cast-iron is capable of bearing a strain of 15,300 pounds without permanent deflexion, we get for the relation of the strain, and the thickness of a tooth capable of sustaining it, the simple expression

$$\frac{\mathrm{H}}{4v} = d^2 \text{ (very nearly)}$$

where $d^2$ is the square of the thickness of the tooth. But the tooth should be capable of resisting this strain when one-third of its thickness is worn away by friction. The tooth should therefore be capable of sustaining $2\frac{1}{4}$ times the strain which is implied in the expression. In other words, the expression

$$\frac{\mathrm{H}}{4v} = d^2, \text{ in practice becomes } \frac{9\mathrm{H}}{16v} = d^2,$$

and this last may be put for the purpose of facilitating the calculation which it involves in the form

$$\frac{3}{4}\sqrt{\frac{\mathrm{H}}{v}} = d,$$

which is a general practical rule for the thickness of cast-iron teeth of wheels. It may be put into words thus :—" Find the number of horses' power which are equivalent to the power of the first mover of the train of machinery, and divide the number by the velocity in feet per second of the pitch line of the pinion or wheel ; extract the square root of the quotient, and three-fourths of this root will be the least thickness in inches of the teeth for the wheel or pinion."—*(Buchanan's Essays on Mill-work, New Edition.)*

This rule enables us to find readily the pitch which any cast-iron wheel ought to have, the power and velocity at the pitch line being known : the clearance of the tooth being taken at $\frac{1}{10}$ of the thickness, we have 2·1 as a constant multiplier for $d$; that is, imbodying the rule in one expression, we have

$$\frac{3}{4}\sqrt{\frac{\mathrm{H}}{v}} \times 2{\cdot}1 = \mathrm{P}, \text{ the pitch.}$$

As an example—let the power of the first mover be 15 horses, and the velocity at the pitch line 3 feet per second.

$$\text{Here } \frac{3}{4}\sqrt{\frac{\mathrm{H}}{v}} = \frac{3}{4}\sqrt{\frac{15}{3}} = \frac{3}{4}\sqrt{5} = 1{\cdot}677$$

the thickness of the teeth ; and this multiplied by 2·1 gives $3\frac{1}{2}$ inches (nearly) for the pitch.

The following table is calculated by this rule, or rather from the more convenient formula $\mathrm{H} = \frac{\mathrm{P}^2 \times v}{2{\cdot}5}$, in which 2·5 is used instead of 2·48, as found by the rule. The table embraces all the pitches enumerated at the beginning of this article, and shows the number of horses' power when the pitch line moves with a given velocity to which they severally correspond.

TABLE OF PITCHES OF WHEELS.

| Pitches in inches. | Thickness of teeth in inches. | H. P. at 3 feet in 1″. | H. P. at 4 feet in 1″. | H. P. at 5 feet in 1″. | H. P. at 7 feet in 1″. | H. P. at 11 feet in 1″. |
|---|---|---|---|---|---|---|
| 4 | 1·9 | 19 | $25\frac{1}{2}$ | 32 | 45 | $70\frac{1}{2}$ |
| $3\frac{1}{2}$ | 1·6 | $14\frac{3}{4}$ | $19\frac{1}{2}$ | $24\frac{1}{2}$ | $34\frac{1}{4}$ | 54 |
| 3 | 1·4 | 11 | $14\frac{1}{2}$ | 18 | 25 | $39\frac{1}{2}$ |
| $2\frac{1}{2}$ | 1·2 | $7\frac{1}{2}$ | 10 | $12\frac{1}{2}$ | $17\frac{1}{2}$ | $27\frac{1}{2}$ |
| 2 | ·95 | $4\frac{3}{4}$ | $6\frac{1}{4}$ | 8 | 11 | $17\frac{1}{4}$ |
| $1\frac{3}{4}$ | ·83 | $3\frac{1}{2}$ | 5 | $6\frac{1}{4}$ | $8\frac{1}{2}$ | $13\frac{1}{2}$ |
| $1\frac{1}{2}$ | ·71 | $2\frac{3}{4}$ | $3\frac{1}{2}$ | $4\frac{1}{2}$ | $6\frac{1}{4}$ | 10 |
| $1\frac{1}{4}$ | ·59 | 2 | $2\frac{1}{2}$ | $3\frac{1}{8}$ | $4\frac{2}{5}$ | $6\frac{4}{5}$ |
| $1\frac{1}{8}$ | ·53 | $1\frac{1}{2}$ | $2\frac{1}{4}$ | $2\frac{1}{2}$ | $3\frac{1}{2}$ | $5\frac{1}{2}$ |
| 1 | ·48 | $1\frac{1}{5}$ | $1\frac{3}{5}$ | 2 | $2\frac{4}{5}$ | $4\frac{2}{5}$ |
| $\frac{7}{8}$ | ·41 | 1 | $1\frac{2}{5}$ | $1\frac{3}{4}$ | $2\frac{1}{2}$ | $3\frac{4}{5}$ |
| $\frac{3}{4}$ | ·36 | $\frac{7}{10}$ | $\frac{9}{10}$ | $1\frac{1}{8}$ | $1\frac{1}{2}$ | $2\frac{1}{2}$ |
| $\frac{5}{8}$ | ·33 | $\frac{1}{2}$ | $\frac{5}{8}$ | $\frac{3}{4}$ | 1 | $1\frac{7}{10}$ |
| $\frac{1}{2}$ | ·24 | $\frac{3}{10}$ | $\frac{2}{5}$ | $\frac{1}{2}$ | $\frac{7}{10}$ | $1\frac{1}{10}$ |
| $\frac{3}{8}$ | ·18 | $\frac{1}{5}$ | $\frac{1}{4}$ | $\frac{3}{10}$ | $\frac{2}{5}$ | $\frac{3}{5}$ |
| $\frac{1}{4}$ | ·12 | $\frac{3}{40}$ | $\frac{1}{10}$ | $\frac{1}{8}$ | $\frac{7}{40}$ | $\frac{11}{40}$ |

This table serves when the velocity is 6 feet, 8 feet, and 10 feet, per second. To find the power when the velocity is 6 feet, we require simply to double the results in the 3 feet column ; and similarly for 8 feet and 10 feet—it is only necessary to double the results in the columns containing the H. P. for 4 feet and 5 feet in the second. Should the velocity be 12 feet per second, we may either multiply the results of the column of 4 feet velocity, or add together those in the columns of 5 feet and 7 feet ; and so on of any higher velocities.

For the sake of comparison, we append two tables, both of which are in use, from Buchanan's Essay on the Teeth of Wheels.

Mr Roberton's table is thus formed :—" *The thickness of the teeth*, in each of the lines, is varied one-tenth of an inch. *The breadth of the teeth* is always four times as much as their thickness. *The strength* of the teeth is ascertained *by multiplying the square of their thickness into their breadth*, taken in inches and tenths, &c. The *pitch* is found *by multiplying the thickness of the teeth by* 2·1. The number that represents the strength of the teeth, will also represent the number of horses' power, at a velocity of about four feet per second. Thus, in the table where the *pitch is* 3·15 *inches*, *the thickness* of the teeth 1·5 *inches*, and the *breadth* 6 *inches*, the strength is valued at $13\frac{1}{2}$ *horses' power*, with a *velocity of four feet per second* at the pitch line."

Mr Carmichael's rule is more concise. It is stated thus :—" Multiply the breadth of the teeth by the square of the thickness, and divide the product by the length. The quotient will be the proportionate strength in horses' power, with a velocity of 2·27 feet per second."

Both of these rules are vitiated by the assumption that the strength increases indefinitely with the breadth, whereas the length and breadth bear a fixed ratio to each other in point of maximum strength. It is not, however, to be supposed that modern practice is wrong in giving a greater breadth to the teeth than the mere calculation of strength points out. On the contrary, it may be proved that the durability is nearly in direct proportion to the breadth, and inversely, as the pressure—and, in consequence, the breadth should considerably exceed the limiting ratio of strength.

A very safe rule for the breadth of teeth is $2 \times \frac{\mathrm{H}}{v}$, that is—Divide the horse power of the first mover by the velocity of the pitch circle in feet per second, and multiply the quotient by 2, for the breadth in inches. Thus, supposing the power equal to 14 horses, and the velocity 7 feet per second, then,

$$2 \times \frac{\mathrm{H}}{v} = 2 \times \tfrac{14}{7} = 4 \text{ inches in breadth.}$$

Mr Rennie uses 1·8 as the co-efficient of $\frac{\mathrm{H}}{v}$, which, in the example above, gives 3·6 inches as the breadth.

MR ROBERTON'S TABLE OF PITCHES. &c.

| Pitch in Inches. | Thickness of Teeth in Inches. | Breadth of Teeth in Inches. | H. P. at 4 feet in 1″. | H. P. at 3 feet in 1″. | H. P. at 6 feet in 1″. | H. P. at 8 feet in 1″. |
|---|---|---|---|---|---|---|
| 3·99 | 1·9 | 7·6 | 27·43 | 20·57 | 41·14 | 54·85 |
| 3·78 | 1·8 | 7·2 | 23·32 | 17·49 | 34·98 | 46·64 |
| 3·57 | 1·7 | 6·8 | 19·65 | 14·73 | 29·46 | 39·28 |
| 3·36 | 1·6 | 6·4 | 16·38 | 12·28 | 24·56 | 32·74 |
| 3·15 | 1·5 | 6· | 13·5 | 10·12 | 20·24 | 26·98 |
| 2·94 | 1·4 | 5·6 | 10·97 | 8·22 | 16·44 | 21·92 |
| 2·73 | 1·3 | 5·2 | 8·78 | 6·58 | 13·16 | 17·54 |
| 2·52 | 1·2 | 4·8 | 6·91 | 5·18 | 10·36 | 13·81 |
| 2·31 | 1·1 | 4·4 | 5·32 | 3·99 | 7·98 | 10·64 |
| 2·1 | 1·0 | 4· | 4·0 | 3·0 | 6·0 | 8·0 |
| 1·89 | ·9 | 3·6 | 2·91 | 2·18 | 4·36 | 5·81 |
| 1·68 | ·8 | 3·2 | 2·04 | 1·53 | 3·06 | 3·08 |
| 1·47 | ·7 | 2·8 | 1·37 | 1·027 | 2·04 | 2·72 |
| 1·26 | ·6 | 2·4 | ·86 | ·64 | 1·38 | 1·84 |
| 1·05 | ·5 | 2· | ·5 | ·375 | ·75 | 1· |

MR CARMICHAEL'S TABLE OF PITCHES, &c.

| Pitch in inches. | Thickness of teeth in inches. | Breadth of teeth in inches. | Length of teeth in inches. | H. P. at 2·27 feet in 1″. | H. P. at 3 feet in 1″. | H. P. at 6 feet in 1″. | H. P. at 11 feet in 1″. |
|---|---|---|---|---|---|---|---|
| 3·99 | 1·9 | 7·6 | 2·28 | 12·03 | 15·90 | 31·80 | 58·30 |
| 3·78 | 1·8 | 7·2 | 2·16 | 10·80 | 14·27 | 28·54 | 52·32 |
| 3·57 | 1·7 | 6·8 | 2·04 | 9·63 | 12·72 | 25·54 | 46·68 |
| 3·36 | 1·6 | 6·4 | 1·92 | 8·53 | 11·27 | 22·54 | 41·32 |
| 3·15 | 1·5 | 6·0 | 1·80 | 7·50 | 9·91 | 19·82 | 36·33 |
| 2·94 | 1·4 | 5·6 | 1·68 | 6·53 | 8·63 | 17·26 | 31·64 |
| 2·73 | 1·3 | 5·2 | 1·56 | 5·63 | 7·44 | 14·88 | 27·28 |
| 2·52 | 1·2 | 4·8 | 1·44 | 4·80 | 6·34 | 12·68 | 23·24 |
| 2·31 | 1·1 | 4·4 | 1·32 | 4·03 | 5·32 | 10·64 | 19·54 |
| 2·10 | 1·0 | 4·0 | 1·20 | 3·33 | 4·40 | 8·81 | 16·15 |
| 1·89 | 0·9 | 3·6 | 1·08 | 2·70 | 3·57 | 7·14 | 13·09 |
| 1·68 | 0·8 | 3·2 | 0·96 | 2·13 | 2·81 | 5·62 | 10·33 |
| 1·47 | 0·7 | 2·8 | 0·84 | 1·63 | 2·15 | 4·30 | 7·88 |
| 1·26 | 0·6 | 2·4 | 0·72 | 1·20 | 1·59 | 3·18 | 5·83 |
| 1·05 | 0·5 | 2·0 | 0·60 | 0·83 | 1·10 | 2·20 | 4·03 |

# ANATOMY AND PHYSIOLOGY.

## CHAPTER XII.

### THE JOINTS.

The bones composing the skeleton are articulated, or joined, to one another, in three different ways. 1st, They are found dove-tailed into one another, with the intervention of a very thin layer of cartilage, and are quite immovable. 2d, They are connected by means of one or more layers of cartilage between them, and ligaments or fibrous bands on their outsides, tying them together, and admitting of more or less motion. 3d, They are united by means of cartilages, ligaments, and synovial membranes, which united apparatus form the most perfect joints, such as are found between the bones of the extremities.

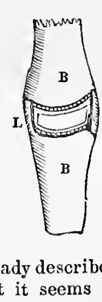
The unions of the bones of the cranium are called *sutures*, from the Latin word signifying to sew, because they seem as if stitched together; the fibres of the one bone forming prolongations which pass into the notches or spaces left by the similar prolongations of the other, as is seen in the figure of the skull already given at p. 296, *ante*. Between these runs a thin layer of cartilage. These sutures run in determinate lines over the head, as seen in the drawing of the cranium just referred to; but, in an article of this kind, for popular reading, it would be out of place to give a more detailed description of them.

The bones of the spine are united by thick layers of a peculiar cartilage, mixed with ligaments, placed between them, admitting of but little motion between any pair of bones, but allowing considerable curvatures to take place in the whole length of the spine. The reason of this arrangement obviously is, that the spinal marrow which is contained in the canal formed by the contiguous rings of the twenty-four vertebræ, may not be subjected to any injurious pressure or twisting at any one point; and the proof of this remark again is, that when a man has his spine fractured or dislocated, the spinal marrow is either torn through, or pressed upon so as to be unfit for its office, or an inflammation is excited in it, which results in its destruction, so that incurable palsy, and a piecemeal death, are sooner or later the results. Strong ligaments also pass down the spine in front and behind, binding its different pieces together. A very beautiful adaptation of the joints of the spine to the habits of its possessor may be observed in a cod, salmon, or other large fish, where the opposed surfaces of the vertebræ will be found hollowed so as to form two cups, between which an almost jelly-like cartilage serves as a ball, thus completing a double ball-and-socket-joint. In the human spine, because its motions are not required to be so extensive, the resemblance to a ball-and-socket-joint is but remote, yet still the principle on which it is formed is quite the same.

*Ligaments*, it should be stated, are composed of numerous straight fibres collected together, and arranged into short bands of various breadth, parallel or radiating, and interwoven with others which cross them, so that they cannot, even on the dissecting-table, be split up into threads. Sometimes the ligament is so formed as to surround the articular ends of two bones which move upon one another, and here it is called a *capsule*, or *capsular ligament.* Ligaments are not extensible nor elastic; hence, when any attempt is made to stretch them too far, great pain is the result, and inflammation follows, and they are said to be *sprained*,—if the force applied be greater still, they may even be entirely ruptured.

The different parts of the pelvis are united by means of cartilage and ligaments, each bone having its articular surface covered with cartilage; and these are laid together, with or without the intervention of a third layer, and are bound firmly by ligaments passing over them. Such are the joints between the two haunch-bones, and between them and the rump-bone.

The joints of the extremities, it has already been remarked, are of a more complicated nature. The ends of the bones entering into the joints, having their forms adapted to one another, are covered with cartilage, then they are tied together by ligaments; and, in addition, a membrane called *synovial*, is spread over the ends of the bones and lines the ligaments, forming a shut bag, whose inner surfaces are everywhere in contact, and to obviate friction are moistened with a bland mucilaginous fluid, called *synovia*. The synovial membrane has a smooth velvety surface, like the membrane which lines the mouth and nose. The fluid which serves the purpose of oil to the joints, does not, in reality, contain any oil, yet it has very much the feeling of oil when rubbed between the fingers. When it increases too much in quantity it produces dropsy of the joints.




The figure in the margin is a plan of a finger joint, one of the simplest of the perfect joints. B B are the two bones; L L, the two side ligaments, which may be felt at the sides of the finger, tying together those parts of the two bones between which there is the least motion. The cartilages are seen marked by cross lines, covering the ends of the bones, and inside of these, the synovial membrane is seen lining both them and the ligaments. A space is represented within the joint, merely for the sake of making its component parts plainer; but, in reality, there is no space or cavity within a joint, all the surfaces being in close contact.

The structure of articular cartilage has been already described in p. 268; it is only necessary here to remark, that it seems to prevent any of that jarring which might be expected to result, were the hard surfaces of bones to be brought with violence immediately into contact.

The motions permitted in joints may be referred to four heads; viz., gliding, flexion and extension, circumduction, and rotation. 1st, *Gliding* is the simple movement of one articular surface upon another, and exists to a greater or less extent in all the joints. In the least moveable joints, as those of the solid parts of the hands and feet this is the only motion which is permitted

2d, *Angular movement* is seen most simply in the joints of the fingers, where no other motion is permitted but that of *flexion* and *extension*. At the joint between the metacarpal bone and first bone of the finger, *adduction* and *abduction* are also permitted; that is, approaching to or removing from its next neighbour. 3d, *Circumduction* consists in the performance of these four motions consecutively, flexion, abduction, extension, adduction, as is seen in making the point of the fore-finger describe a circle, having the metacarpal joint for its centre. 4th, *Rotation* is the rolling of a bone upon its own axis, as is seen in the hip and shoulder-joints, the upper end of the radius in pronation and supination of the hand, and the articulation between the first and second vertebræ of the neck, when the head is turned shortly round from side to side.

The head is set upon the first vertebra of the neck, through the medium of a couple of joints, admitting of only flexion and extension. When a quick short nod of the head is given, the motion takes place here. The first vertebra of the neck is a circle moving round a pin projecting from the second vertebra—thence called the *axis*—carrying the head round with it, in the quick short movement of looking sidewise. The only complete dislocation that takes place in the spine is at this joint, in consequence of the destruction of a ligament which keeps the bones in their places. When this happens the weight of the head makes it fall forward, carrying the first vertebra with it, and the spinal marrow is so nipt between its ring and the projecting pin of the second, that the sufferer dies as surely and as instantaneously as if his neck were severed by the axe of the executioner. In a man, who is hanged, too, this is generally the cause of death; not, indeed, in one who deliberately suspends himself in his own handkerchief; but the criminal who is launched from the drop, with a fall of several feet, and dies instantaneously, has his neck dislocated, while he who struggles perishes from suffocation.

The articulation of the lower jaw, with the temporal bone, is almost completely a hinge-joint. The upper end, or *condyle*, of the jaw-bone is covered with cartilage, and so is the socket, and the two bones are tied together by side ligaments. Besides, there is a moveable cartilage in the joint which accompanies the condyle of the jaw in its motion. Notwithstanding all these appliances, the jaw is sometimes dislocated, slipping forward off the eminence upon which it gets when the mouth is opened. When this accident takes place, which generally happens from a violent yawn, the patient is left with his mouth wide open, and has not the power of closing it, presenting a very ludicrous figure to his companions, though his situation is to himself sufficiently uncomfortable. After this dislocation has happened it is exceedingly liable to be reproduced, in consequence of the torn ligaments never properly uniting. The story has been often enough told of the surgeon who was dissatisfied with the scurvy fee offered him for reducing a gentleman's jaw, sitting down and exciting a yawn by telling a tiresome story, and opening and shutting his snuff-box lid, till the patient's jaw opened and slipped out again, and then refusing to replace it until a handsome *honorarium* was laid upon the table.

Strong bands of fibres tie the collar-bone to a slight hollow in the upper corner of the breast-bone; the motion is very free, and to render it the more so, a moveable cartilage is interposed between them. This joint is very rarely indeed injured. The collar-bone and shoulder-blade are very firmly bound together so as to move as one piece, and yet a slight yielding is permitted, otherwise, as they stand at right angles to one another, fracture or dislocation, about this joint, would much more frequently occur.

The shoulder-joint is of all others the most frequently dislocated. This results partly from its form, and partly from its being more exposed to violence—since every fall, whether upon the shoulder, arm, or hand, has a tendency to displace it. The cavity on the shoulder-blade is so small and shallow, that the round head of the arm-bone is laid not in it, but on it; its barrel-shaped capsular ligament is strong, but loose, so that the bone depends for being retained in its place, upon the muscles which surround it; and if these be overcome, or taken by surprise, particularly when the arm is raised above the head, the head of the bone is dislocated down into the arm-pit. It is, in general, replaced without much difficulty, but is exceedingly liable to be thrown out again. The author recollects one man, who fell into fits occasionally, whose shoulder-joint he saw dislocated, and assisted to reduce, three times, on three successive days. The shoulder-joint admits all the varieties of motion described in a preceding paragraph.

The elbow-joint is more complex than the shoulder. It is double in its motions, admitting of the flexion and extension of the fore-arm on the arm, and the rolling of the head of the radius. For the first motion it has two strong lateral ligaments, which may be felt at the two sides, rendering it a hinge-joint; and, for the second, the neck of the radius is confined to the side of the ulna by a collar in which it rolls. A synovial membrane covers the ends of the bones, and lines the different ligaments. It may be dislocated in many directions. Both bones of the fore-arm are, most commonly, thrown backward, as in consequence of a fall on the hand—then the arm is nearly straight, and cannot be bent. Sometimes the fore-arm is thrown sideways, either outward or inward, and sometimes the radius is dislocated alone—backwards, forwards, or outwards. From its complexity it is also exceedingly subject to disease.

The wrist is a hinge-joint, moving backwards and forwards, and also allowing the hand to be carried a little edgewise, outwards or inwards. The lower end of the radius forms a socket in which the uppermost two bones of the wrist move, united so as to form an oblong ball. Two lateral ligaments confine the hand to the lower ends of the radius and ulna, and the whole joint is lined by a synovial membrane. This joint is almost never dislocated; but it is liable to sprains, and to disease, producing occasionally the loss of the hand.

Closely connected with the wrist-joint, although not actually forming a part of it, is the joint between the lower ends of the radius and ulna. Here there is a socket in the edge of the radius, which is made to revolve round the small lower end of the ulna which remains fixed, while the hand is thrown, alternately with its palm and its back, forwards.

The bones of the hand are not subject to dislocations, except at the joint between the first and second pieces of the thumb—a seemingly trifling affair; but one which is extremely difficult to set to rights—so much so, that many of those who are the subjects of this accident, continue to go with the point of the thumb bent back all the rest of their days.

The hip-joint consists of a deep socket in the haunch-bone, into which the round head of the thigh-bone is set. A capsular ligament, of great strength, of a barrel-shape, attached round the edge of the socket and to the neck of the bone, fixes it in its place. The opposed surfaces of the bones are covered with cartilage and are tied together by an internal ligament. A new explanation of the use of this ligament has been given within the last few years, from which it would seem that, as its attachment to the thigh-bone is on a higher level than its connexion to the bottom of the socket, the superincumbent weight rather swings from, than rests on, the head of the thigh-bone. The whole is lined with a synovial membrane. This joint, notwithstanding its strength, is subject to dislocation, principally on account of the long lever which the thigh-bone affords to any force acting upon it, so as to tear the head from its socket.

The knee is the most complicated joint in the whole body. The ends of the thigh-bone and *tibia* are each covered with cartilage, and in contact, but neither of them is hollowed—so that the joint does not depend for strength on its form, but on the number and strength of its ligaments. Two of these are placed externally and internally—as in all hinge-joints—and seven others are arranged, in different positions, within and without it. The knee-pan is placed in front of it, and the whole is lined with a synovial membrane, which is the largest in the body—hence the fever and extreme constitutional disturbance that arise when this joint becomes inflamed. It lies very superficial, being covered only by the skin in the greatest part of its extent; and hence it is very easily wounded by a cut or prick from any sharp instrument. It is never dislocated, except by such a force as destroys it altogether, and necessitates the immediate removal of the limb by amputation.

The ankle is a hinge-joint, having one lateral ligament on its inner, and three on its outer side. The upper surface of the *astragalus*, as has been already said (p. 297, *ante*), is like the half of a broad pulley; it plays against the lower hollow end of the *tibia*, and is received between the two ankles, formed by it and the *fibula*. This part of the *astragalus* is narrower behind than in front, so that when the foot is at right angles to the leg, as we stand on it, the broad part is between the ankles, and it is firmly fixed; but when the foot is extended, pointed downward, the

narrow part is brought between them, so as to admit of the toes being directed to either side. The ankle-joint may be dislocated forwards, or to either side. This never happens without one of the ankles being broken off, the ligaments being so strong that the bone will break rather than they should give way. The dislocation of the ankle can scarcely take place without a wound coexisting. And here is a suitable opportunity for explaining what is meant by a simple, and what by a compound dislocation.

A *simple dislocation* is one where the bones are displaced, but the joint is not laid open; a *compound* one need not be more serious in so far as the bones are concerned, but is accompanied with a wound leading into the joint, which, consequently, inflames and suppurates, and brings the sufferer into great danger of losing his limb, if not his life. In the same way, a *simple fracture* is when a bone is broken without a wound; a *compound* one is where there is a wound communicating with the broken surfaces.

The joints across the foot are numerous, and not easily described in a treatise of this kind. There is one joint across the middle of the *tarsus*, or solid part of the foot, which, in some persons, admits of a good deal of lateral motion; and, in such feet, is liable to be sprained. Another joint runs across between the bones of the *tarsus* and those of the instep. An accurate knowledge of these joints is necessary to the surgeon; for in those severe accidents which are constantly occurring to the labouring population, where a part of the foot is crushed, he is often enabled to preserve a useful foot, by cutting away the injured part, at one of those joints, leaving still the heel to rest upon, and an artificial apparatus is adapted to the stump, to represent the anterior part of the foot. The joints of the toes require nothing particular to be said of them—only that they are similar to those of the fingers, but much smaller. In persons who drink much wine, they are apt to become affected with gout; and in elderly people, the joint at the ball of the great toe is apt to be drawn, so as to make an ugly projection on the inner side of the foot—become exposed to pressure from the shoe, and so produce a corn, which, from its situation, is incurable.

The most common disease of joints is their inflammation. Sometimes this is acute, as after injuries, or from rheumatism. The synovial bag becomes inflamed, and forms an inordinate quantity of fluid, which distends the joint enormously. It is accompanied with intense redness and acute pain, and requires bleeding and other such treatment, to reduce it. In scrofulous persons, the inflammation does not assume this acute form, but is low and long-continued; the synovial membrane forms purulent matter, instead of merely an increased quantity of its natural secretion; the matter gradually works its way to the surface, making one or two ulcerated openings, leading directly into the joint; and, by and by, the cartilages are destroyed—so that, if a probe be introduced, the ends of the bone are felt to be bare and rough. In this state the patient's general health suffers much; he becomes affected with shiverings, profuse night-sweats, and purgings, and unless the limb were amputated, he would speedily die. In the cases of the shoulder and elbow, an operation has come much into use within the last twenty years, by which an incision is made through the skin, and the diseased ends of the bones cut out; a new false joint forms, and the use of the limb is, in a great measure, recovered.

## MATHEMATICS.

### CHAPTER IX.

#### ABBREVIATIONS IN THE MULTIPLICATION AND DIVISION OF DECIMAL FRACTIONS.

The rules already given for the operations of multiplication and division of decimals, are generally applicable; but it frequently happens that the work is more laborious than is necessary to obtain the degree of accuracy which the results are required to have. Thus, supposing it is required to find the product of 5·247 multiplied by 3·365, true to two places of decimals only, the rule given does not furnish us with any other mode of proceeding than that of making the full multiplication, and afterwards abridging the result. The actual result is

$$5{\cdot}247 \times 3{\cdot}365 = 17{\cdot}656155,$$

which, made true to two places, is 17·66. Here, then, we have found four places of decimals more than were wanted.

It might, at first sight, appear that this superfluous labour might be somewhat abridged, by abridging our multiplicand and multiplier previous to making the multiplication. Were we to attempt such a modification of the process, it would be at the expense of accuracy. Thus, supposing we reduce our factors by one place each, and make the multiplication, we then have

$$5{\cdot}25 \times 3{\cdot}37 = 17{\cdot}6925.$$

Here we have still two places more than are wanted; and, what is more, the second place is incorrect. The reason of this is very obvious. The error introduced by taking 5·25, instead of 5·247, has been taken 3·37 times, and the error made by taking 3·37, instead of 3·365, has been taken 5·25 times; and the product, 17·6925, contains the sum of these multiplied errors. The sum of these errors is ·036345,* which, taken from 17·6925, leaves 17·656155, the product found by the first process. But we have only been able to make the correction by a knowledge of the original errors.

This mode is, then, both laborious and deficient in point of accuracy. To replace it by a rule which has neither of these defects, it is, however, necessary, in the first place, to premise that in any case of multiplication, we may write the figures of the multiplier in a contrary order—(for example, 1635, instead of 5361)—provided that, in the operation, we move each line one place to the right instead of moving it to the left. This is shown in the following instance, in which the operation is given at full length, according to both methods:

| Common Method. | With Multiplier inverted. |
|---:|:---|
| 31215 | 31215 |
| 5361 |  1635 |
| 31215 | 156075 |
| 187290 |  93645 |
| 93645 |   187290 |
| 156075 |    31215 |
| 167343615 | 167343615 |

The results are here the same; and the reason is at once obvious, from an inspection of the two processes.

Suppose now that we wish to multiply 5·247 by 3·365, in such a way as to obtain a product correct to two places of decimals, we have only to apply this principle, taking care to place that figure in the reversed multiplier, which occupied the unit's place, immediately under the second place of decimals in the multiplicand. The process is written below.

| | |
|---:|:---|
| 5.24 | 7 |
| 56 | 33 |
| 1574 | 1 |
| 157 | 41 |
| 31 | 482 |
| 2 | 6235 |
| 17·65 | 6155 |

Here we have cut off, by a vertical line, the four places of decimals which are not wanted in the result. But it is very plain that had we neglected these figures entirely, our product would have been faulty; for, looking at the first column on the left of the vertical line, we find 4, 7, 1, 2, of which the first figure, 4, comes from† $4' \times 3''$; the 7, from $2' \times 3''$; the 1, from $5' \times 6''$; and the 2, from $0' \times 5''$—together with the carriage from the preceding multiplications. Were it not, then, that there are certain figures to be carried from right

* This is not strictly the sum of the errors referred to, but the real amount of error committed—which, expressed generally, is $A\,a + B\,b - a\,b$, where A and B are the altered factors, and $a$ and $b$ the errors of alteration. As $a$ and $b$ are, however, very small, $a\,b$ may be neglected, since it must be greatly smaller than either $a$ or $b$. Thus, in the example, $a = {\cdot}003$ and $b = {\cdot}005$; therefore, $a\,b = {\cdot}000015$. The following is a very simple rule for judging how far a product obtained from two contracted factors can be relied upon. Thus, taking A and B as the factors, if they are true to only one decimal place, then their product is within $\frac{A + B}{20}$; of the truth; if they are true to two decimal places, then the product is within $\frac{A + B}{200}$; if to three, within $\frac{A + B}{2000}$; and so on. Thus, taking the values of A and B, in the example, which are true to two places, we have $\frac{5{\cdot}25 + 3{\cdot}37}{200} = {\cdot}0431$, for the possible error in their product, 17·6925; so that the true answer must be between $17{\cdot}6925 - {\cdot}0431 = 17{\cdot}6494$, and $17{\cdot}6925 + {\cdot}0431 = 17{\cdot}7356$; but at what point the rule does not enable us to determine.

† The ′ means that the figure over which it is placed is in the multiplicand, and ″, that is in the multiplier.

to left of the vertical line, we might proceed with the multiplication, commencing always with that figure of the multiplicand which is immediately over the figure of the multiplier, taking no account of those to the right. But we may observe, from the example, that it is necessary to consider, both what is carried directly in the formation of the different lines and what is carried from the addition of the first column on the right. Now, the first of these may be allowed for, by carrying the tens which result from the multiplication of the figure immediately on the right of that above the figure of the multiplier ; and both corrections may be allowed for at once, by taking the nearest number of tens in that product ; that is, by carrying 1 from 5 up to 15 ; 2 from 15 up to 25 ; 3 from 25 up to 35—and so on. Thus, for 24, we carry 2, but for 26, we carry 3—because 24 is more nearly 2 tens than 3 tens, and 26 is more nearly 3 tens than 2 tens. We shall now write the example in this abridged form, with the explanation of the several steps upon the right.

| | |
|---|---|
| 5·247<br>5633 | Multiplier reversed ; units' figure falling under second decimal place of multiplicand. |
| 1574 - | Product by 3 ; figure to begin with 4 ; but 3 times 7=21 ; nearest tens 2, which carry to 4×3 making 14 ; put down 4 and carry 1 ; the rest as usual. |
| 157 - | Product from second 3 of multiplier ; figure to begin with 2; figure to carry 1 from 4×3; rest as usual. |
| 31 - | Product from 6 ; figure to begin with 5; figure to carry 1 from 2×6; rest as usual. |
| 3 - | Product from 5 ; figure to begin with 0 ; carriage figure 3 from 5×5. This is equally near 2 tens and 3 tens ; but we at once see that, by going back another step, we would have obtained a carriage of 1 making 26. |
| 17·65 | |

It will here be observed, that our rule has failed to give us the nearest possible value of 5·247 × 3·365 to two places of decimals, a nearer approximation being 17·66. The error is, however, very small, and if greater accuracy be required than the rule ensures, it may be obtained by finding a decimal place more than is wanted, and striking it off after the addition is made. The rule, then, may be stated as follows :—

To multiply two decimals together retaining only $n$ decimal places—

I. Reverse the multiplier, striking out the decimal point, and place it under the multiplicand in such a way that what was its units' figure shall fall under the $n$th decimal place of the multiplicand, placing ciphers, if necessary, on the right of the multiplicand, so that every figure of the multiplier shall have a figure or cipher above it.

II. Multiply, as usual, with this difference, that each figure of the multiplier must begin with the figure of the multiplicand which comes immediately over it, taking care to add to the product the nearest number of tens which would be obtained by the multiplication of the figure immediately on the right of that taken.

III. Place the first figures of all the lines under one another ; add as usual, and mark off $n$ places from the right for decimals.

The following examples will fully illustrate this rule. The first two lines are the multiplicand and multiplier, and the number of decimal places to be retained will be seen from the results.

| | | |
|---|---|---|
| 36·3771 | ·0699268 | 3·4641016 |
| 9·99339 | ·9975641 | 17·32508 |
| 363771 | ·0699268 | 346410160 |
| 933999 | 14657990 | 8052371 |
| 327394 | 629341 | 346410160 |
| 32739 | 62934 | 242487112 |
| 3273 | 4894 | 10392305 |
| 109 | 350 | 692820 |
| 11 | 42 | 173205 |
| 3 | 3 | 2771 |
| 363·529 | ·0697564 | 60·0158373 |

Division admits of a simplification analogous to that explained for multiplication. Thus, supposing 320·31768 is to be divided by 93·4525, and only six places of decimals be required—we proceed as follows :—

Having found the two first figures 3·4 in the usual manner, we suppress the right hand figure 5 of the divisor instead of annexing a cipher to the remainder, as in the common process. To find the next partial quotient 2, we have therefore for dividend 257918 and divisor 93452, with any carriage which may arise from the suppressed figure 5. The operation gives us, for the next remainder, 71013, which is to be divided by 9345 for the next partial quotient 7. This gives us a remainder, 5597, to be divided by 934 for another quotient figure 5. And so on. As in multiplication it is necessary, each time, that a figure is neglected from the divisor to add to the following product the tens which that figure would have given. The process may now be put into the form of a rule thus—

| | | |
|---|---|---|
| 934525) | 3203176·8 | (3·427599 |
| | 2803575 | |
| | 3996018 | |
| | 3738100 | |
| 93452 | 5)257918 | |
| | 186905 | |
| 9345 | 25)71013 | |
| | 65416 | |
| 934 | 525)5597 | |
| | 4673 | |
| 93 | 4525)924 | |
| | 841 | |
| 9 | 34525)83 | |
| | 81 | |
| | 934525)2 | |

To divide one decimal by another retaining only $n$ places of decimals in the quotient.

Proceed one step in the ordinary division and determine what part of the quotient the figure is which is thereby found. Proceed in the ordinary way until the number of figures remaining to be found be at least one less than the number of figures in the divisor ; then, instead of annexing ciphers in the ordinary way, abridge the divisor one figure at each step, taking care in multiplying the abridged divisor to carry the *nearest ten* from the figure which is struck off. Repeat this operation, striking off at every successive step one figure from the divisor until no figures are left ; then, since it is known, from the first, in what place the first figure of the quotient is, and also how many decimal places are required, we can tell from the beginning, how many figures there will be in the whole quotient. Should the divisor contain more figures than are wanted in the quotient they may be struck off before commencing the division ; and if there be ciphers on the left of the divisor they may be omitted, taking care to move the decimal point of the quotient as many places to the right as there were ciphers struck out.

The following examples will fully illustrate the rule. The quotients are written beneath each, to save room, and the number of decimal places required is marked over each example.

| | | | | |
|---|---|---|---|---|
| Dec. places, | | 3 | 9 | 8 |
| Divisor, | | ·31015 | 1·60021 | 3·14159265 |
| Dividend, | | 361·25000* | ·138597 | 1·00000000 |
| | | 310 15 | 1280168 | 94247779 |
| | | 51100 | 105802 | 5752221 |
| | | 31015 | 960126 | 3141593 |
| | | 200850 | 97894 | 2610628 |
| | | 186090 | 960126 | 2513274 |
| | 3101 | 5)14760 | 18814 | 97354 |
| | | 12406 | 16002 | 94248 |
| | 310 | 15)2354 | 2812 | 3106 |
| | | 2171 | 1600 | 2827 |
| | 31 | 015)183 | 212 | 279 |
| | | 155 | 160 | 251 |
| | 3 | 1015)28 | 52 | 28 |
| | | 27 | 48 | 27 |
| | | 1 | 4 | 1 |
| | | | 3 | |
| Quotient, | | 1164·759; | ·086611132 1 | ·31830989 |

* The ciphers are here annexed to reduce the dividend to the same denominator as the divisor: this enables us to see at once the value of the first quotient figure.

As in multiplication, it is always desirable, for the sake of accuracy, to find one place more than is absolutely wanted to be correct.

# THE VOLTAIC BATTERY DISSECTED.

## CHAPTER I.

### VOLTAIC DIAPHRAGMS.

In the entire range of works and memoirs upon Voltaic Electricity, it does not appear that there is anything like a satisfactory explanation of the nature, comparative advantage, and peculiar qualities of the substances employed to separate the two electrolytes in constant voltaic batteries; the consequence is, that men of science—philosophers as well as amateurs—are hampered beyond measure by the failure and improper action of the diaphragms they employ, and are frequently prevented by these causes from prosecuting most important researches. The evil is most severely felt in investigations of a protracted nature, requiring continued electric action for days, weeks, or months; for it is evident that the least injury to the diaphragm, whether as a *conductor* of the current or a *separator* of the fluids, must either destroy or pervert the expected results of perhaps very expensive and laborious experiments. Surely, then, it becomes of no slight importance to trace the causes of the frequent failures of researches, conducted apparently with the greatest care; and point out, so far as experience admits, those means whereby the voltaic battery may be made as perfect and certain in its action as possible.

Taking another point of view, namely, the application of voltaic electricity to the arts—particularly the voltaplastic—where want of *equality* of *action* incontrovertibly produces *inequality* of *effect*, it becomes evident, upon consideration, that the processes of electro-gilding, plating, &c., must be comparatively valueless, so long as the tenacity, solidity, colour, and thickness of the metal deposited, are governed by the use of a *more* perfect or *less* perfect voltaic combination, or of a *more* perfect or *less* perfect voltaic diaphragm. Manufacturers pay but little attention to these points; in fact, very few perfectly comprehend them, being more devoted to business than to study; but we tell them that, in the long run, they will find how very much in error they have been, when their imperfect goods become depreciated in the market; and we further tell them, that, inasmuch as they cannot subvert the immutable laws which govern the effects of electrical action—and one of these laws being that greater or less electrical power, in other words, greater or less *retardation* of the current, must, more or less, alter, disturb, or vary the results—they should consider it of no little advantage to learn how to obtain equality of effect, and how to *preserve* a combination, *originally* good, in perfect working order.

In the present article, it is proposed to limit ourselves to a description of the nature and defects of the various diaphragms employed in constant voltaic batteries, since the period of Becquerel's discovery in 1829, following, as closely as possible, the order of their application. In a future article we shall take the battery to pieces, and develop the most effectual methods of securing and preserving the proper action of the various parts of the combination.

### OF SUBSTANCES USED FOR DIAPHRAGMS.

Before we commence our account of the various diaphragm in present use, it may be well to answer an anticipated question—*videlicet*, What is the object of a Voltaic Diaphragm? Briefly, then, we may reply, that its chief design is to prevent the deposition of *positive* elements on negative surfaces, and *vice versa*—which, by creating *local action*, was the chief cause of the decline of power in the *old* forms of battery; by its use also, it is possible to employ two different solutions, and, at the same time, guard against their *too* intimate mixture; by which means *new* elements of power may be introduced into the combination, and a play of affinities promoted, which not only adds to the conducting power of the *fluid* portion of the battery, but also preserves the *solid*, or metallic portion, in that state which is best adapted for the *proper* development of electric energy. This much for the present; the subject will be considered in greater detail in a future article; and meanwhile we shall proceed with our description of the substances in use for the above purposes.

Although it appears to have been known to Porrett, Ritchie, Ohm, and others, previously to the year 1829, that the voltaic current passed readily through diaphragms of bladder, it does not seem to have struck any of those philosophers, that membranes might be used with advantage in voltaic combinations; it was reserved for M. Becquerel to apply them in conjunction with two distinct solutions, or electrolytes, in the combination discovered by him in the year 1829, with the view of obtaining constancy of voltaic action. The membranous partitions employed by him, as described in the *Ann. de Chim. et de Phys.*, *tome* 41, and other memoirs, were gold-beaters' skin, and the membrane lining the stomach of animals; he also used porcelain clay wetted with a solution of sea salt, and plaster of Paris. Now, it must be evident, that although, on the one hand, such membranes offered the least possible obstruction to the passage of the current, their extreme thinness, on the other hand, rendered them too liable to injury, and therefore unfitted them for use where continued action for a long period was required. The same objection does not, of course, apply to the porcelain clay or plaster of Paris; but of these partitions more anon.

Membranous partitions were next employed in Daniell's "constant," and Mullins' "sustaining" battery, which were introduced in the year 1836. In the former an extremely thick membrane was adopted, namely, an ox-gullet—in the latter, thin bladder was, for the first time, employed; to both of these membranes there were decided objections. The first, in addition to its presenting increased obstruction to the passage of the current, received within its pores a deposit of pure metallic copper, which necessarily created secondary action, and thus diminished the general effect; besides, so soon as the accumulating metal worked through the diaphragm, the latter became leaky, and admitted too great a mixture of the separated solutions; it thus became requisite to change the diaphragms, which, of course, where the experiments were continuous, seriously impeded, and frequently defeated the expected results, to say nothing of the immense trouble and loss of time in refitting membranes in *compound* batteries. In the sustaining battery, the use of bladder was found equally inconvenient; for although, as in Becquerel's invention, the current was *less* retarded than by the use of a *thicker* partition, the membrane was extremely liable to injury, and, after two or three days' use, became loaded with copper, which of course affected the power of the battery. In order to obviate this defect, which Mr Mullins soon perceived to be a serious obstacle to the utility of his combination, he adopted closely woven white silk, which did not cause a greater superficial mixture of the liquids, on either side of the partition, than he found advantageous, and was very durable; but unfortunately a portion of the precipitated copper collected, as in the case of the bladder, within its interstices, though not nearly to so great an extent, but still sufficiently so to affect the action. Mr Mullins subsequently experimented upon various other porous substances, as detailed in his papers in the *Philosophical Magazine*, but, it would appear, with no better results, until the year 1838, when he effected an important improvement, which will be subsequently noticed.

The next improvement in diaphragms was made, we believe, by Mr Mason, who invented vessels of porous biscuit-ware, or of pipe-clay, which, in some respects, are superior to animal membrane, and inferior in others; they last longer if kept moist, but they retard the current considerably, and, after some time, the salts formed during the action of the battery, and, subsequently, crystallize in the pores, and cause them to scale and split in every direction. Another great drawback to their utility is, that, in the progress of their manufacture, some become harder and less porous than others, in consequence of which no two of them will pass the current equally well, which is a serious defect in a *compound* battery. Other experimenters have recommended leather, parchment, thick hempen cloth, and brown paper, but not one of those substances is free from the nuisance of metallic deposition, and, its natural consequence, diminished power. Brown paper admits of too great a mixture and goes to pieces after a few hours' service, and the others retard the current much more than ox-gullet or bladder. There is not, therefore, one of the abovenamed diaphragms that we could conscientiously recommend to any person who wishes to carry on his voltaic researches for *more* than a few hours; but

for those who choose to *limit* their experiments to a few hours' duration, the best of the partitions hitherto described will be found to be those of unglazed earthenware, or pipe-clay; but they are easily broken, and expensive from the necessity of frequent renewal.

We have deemed it advisable to be thus particular in the description of the various substances employed for diaphragms, as well as of the defects which, in employment, they exhibit; for, otherwise, it would be impossible to conquer the prejudices acquired in favour of some one of them, merely because it may have been lauded by some public lecturer, who may have had but little time to devote to the close investigation of their respective merits. Our sincere advice to those who wish to acquire either *knowledge* or *fame* by scientific investigation, *is to think for themselves*, and compare, so far as their means will allow, the various instruments of research which appear most sought after, depending upon their private judgment for the selection. No man should handle a scientific instrument who is not *capable* of properly estimating its value, upon comparison with others.

It now only remains to describe the latest, and decidedly the best, in the long list of voltaic diaphragms—we allude to the *wooden* partition, the invention of Mr Mullins, and adopted by that gentleman, after an unprejudiced investigation of the qualities of the various partitions employed at the time. This diaphragm is made of sycamore, or any other open wood; but sycamore appears to be the best. When required for pot batteries it is turned into the cylindrical form, and of any diameter that may be required; the side of the vessel should not exceed the tenth of an inch in thickness, the bottom is generally half an inch thick. The wood employed should be well seasoned, free from knots and from cross-grain, and be worked in accordance with the natural rings in the wood; these precautions being observed, a diaphragm will be obtained, which, with care, will last for years, and which is perfectly free from metallic deposition, or any fault that can affect the action of the battery. After being turned it must be boiled in soft water, with a small quantity of potash, and subsequently be steeped, for three or four days, in water acidulated with sulphuric acid; this mode of treatment extracts or neutralizes any matter in the wood injurious to conductibility, and, moreover, renders the wood itself tough, and not liable to split on becoming dry; but it will be best to keep the diaphragm, when not in use, in acidulated water, or a saline solution; it will thus be ready for use at any moment, whereas, if allowed to become perfectly dry, it requires an hour to resume its full power of conduction, in which it fully equals thick membranes—such as ox-gullet—and is far superior to porous earthenware; it will be found to improve by use, and is not at all liable to decay. In a paper in the *Phil. Mag.*, Mr Mullins states that one of these diaphragms was in constant use at the London Adelaide Gallery for two years, and was perfectly sound at the end of that period. It is to be particularly observed that those diaphragms—and, indeed, all others—should *not* be left in the battery when out of action; for, if so, saline crystallizations occur upon, and even beneath, the surface, which cannot but injure the diaphragm. The wooden partitions required for square batteries are cut out of sycamore, sawed into thin planks of the substance of veneer, and well seasoned. These diaphragms are in very general use for voltaplastic purposes, and, where the wood has been *properly prepared*, have never failed to give satisfaction. It may be added that, where wooden partitions are employed, a degree of equality of action is acquired, which cannot be attained in any battery without them.

## ON THE PHENOMENA OF CRYSTALLIZATION.

The forms which matter assumes when it enters into the crystalline state are very various. Even the same particles do not invariably take the same mathematical figure under the influence of the molecular force of cohesion. The laws which regulate their aggregation, are continually liable to disturbance from extraneous causes. Among these, the nature of the medium in which crystallization takes place, and the temperature under which the crystal is formed, are perhaps the most easily recognised. Thus, crystals of the same salt formed in a hot and cold solution, under atmospheric pressure, or in a vacuum, are often different in their geometrical characters; and the forms assumed by the same body, when crystallized from fusion and from solution, are very rarely identical. In cases where two distinct geometrical forms of crystals are thus obtained, the body is said to be dimorphous; but if we examine very closely the various forms of crystals of the same substance which we obtain from a solution, or of the same mineral which we obtain naturally crystallized, we have little difficulty in discovering that the dissimilarity is confined to the mere external appearance, and that internally the structure is uniform. Thus, a crop of crystals of alum exhibit many different forms; but if we examine two of the most dissimilar, by dividing with a knife in the direction of their planes of cleavage—which are readily found by trial—we invariably find them reducible to some primary form—the geometrical solid, termed the octohedron. In nature we similarly meet with numerous crystalline forms of carbonate of lime—not less than six hundred; but actual dissection informs us that they are all resolvable into that form called the rhombohedron. It is thus that, notwithstanding the immense variety of forms which crystals assume, they are all reducible to a few classes, and brought within the cognisance of fixed mathematical laws. By dissection, we readily learn that the atoms forming the crystals are built around a certain nucleus, forming layers over its external faces, and determining the ultimate character of the crystal by the degree of regularity maintained during their deposition. But it may further be observed that this central nucleus itself must be a compound structure, built, like the fully developed crystal, around a central atom, and it is not too much to suppose, although experiment does not guide us so far, that the primary form must be regulated by certain points of attraction and repulsion, which determine the law of molecular cohesion in that species of matter of which the crystal is composed.

This atomic polarity is, indeed, one of the first considerations which occur to the mind in studying the phenomena of crystallization. That it really does exist is at once plain from the simple dissection of a crystal. Did the particles attract each other on all sides equally, there could be no planes of cleavage in a crystal—in other words, the crystal might be divided in one direction as easily and as readily as in another. In fact, there could be no determinate form of crystalline arrangement. The atoms aggregating themselves together under the cohesive force would assume no definite structure, and no other geometrical form than that of a sphere modified by the force of gravity.

It is this atomic polarity which has given rise to the plausible hypothesis, that crystallization is referrible to the same law which determines the position of the mariner's needle, when fairly poised. Could we form, with the same accuracy as nature, a great number of particles of steel—all of definite and regular forms, and all equally magnetized; and, farther, could we suspend them in a fluid of exactly their own specific gravity, we might reasonably expect to realize some example of the crystallizing process. We would have the particles adhering together by their opposite poles, and disposed in layers around a central particle, which, having only two poles, would give to the crystal the form of a square prism, which might be divided into cubes by sections across its length. Our crystal would be, of course, but a rude imitation of nature's work, since the finest particle we could form would be itself an aggregate of many of those atoms which go to the composition of a sensible molecule.

That there is a fundamental difference in the laws of molecular cohesion, concerned in the formation of a crystal, is proved by evidence derived from a variety of sources. The peculiar and well-known action which many crystalline bodies exert upon light, furnishes, perhaps, the most direct and extraordinary information of this fact; it is, indeed, to this physical difference of constitution in crystalline bodies that we owe the great increase which has of late been made to our knowledge of the more recondite properties of light.

The opinion entertained with respect to the electric, galvanic, and magnetic forces, is, that they depend on the same ultimate cause, and are, in fact, only modified exhibitions, like light and heat, of one and the same agency. We also know from experiment that a change of temperature—the contact of bodies with each other—rapid and slow cooling—and the application of heat and light—all tend as disturbing causes to change the electric state of bodies. An analogous series of changes is exemplified during the phenomena of crystallization, when the material particles are similarly exposed to extraneous influence. Thus, the

yellow binoxide of mercury, when touched, begins instantly to crystallize, a creeping motion being perceptible in it during the process; at the same time its colour changes to deep scarlet. The often repeated experiment of the crystallization of a quantity of glauber salt which had been poured, while hot, into a stoppered flask, and allowed to cool *in vacuo*, is a similar illustration of the disturbing influence of the atmosphere. The disturbing influence of light is equally remarkable, and is well illustrated by the crystallization of camphor, from its solution when exposed in a glass vessel to the strong light of the sun.

In referring to the analogy which is thus observed to exist between the development of electricity and of crystallization, it is interesting, as affording another link to the series of analogies, to remark the peculiar connexion between the vibration of certain bodies and the formation of crystalline structure. For example, we have no more common experiment than the formation of regular geometrical figures by sand spread upon a plate of glass, when the bow of a violin is drawn across the edge of the glass. Whether this be merely a coincident case, or a fact induced by the same cause which determines the symmetrical arrangement of the particles of matter in crystalline structure, we do not pretend to decide; still, we think that it is not to be overlooked, as it may yet enable us to advance a step towards a physical explanation of the laws which govern the aggregation of those atomic elements, by which material bodies are built up.

The galvanic experiments of Mr Crosse have likewise their interest, and throw considerable light upon the relation which exists between galvanic action and the formation of crystalline structure. These experiments go to show that one species of crystal may be formed in solutions of the salt at the positive pole of the battery, and a different species of crystal at the negative pole. Thus, in a solution of bicarbonate of lime, he obtained at the negative pole the rhombohedral crystal, whereas, at the positive pole, he obtained prismatic crystals of arragonite. Some of these celebrated experiments were as follows:—

"In a cavern, of which the vault is covered with fine crystals of arragonite and carbonate of lime, the water which drops from the vault holds in solution 10 grains of the carbonate, or rather bicarbonate of lime, with a little sulphate of the same to each pint. A glass of this water was submitted to the action of a powerful battery, and in a few days there were formed at the negative pole rhombohedral crystals of the carbonate of lime. Another experiment was by letting the water drop on a piece of brick, subjected to a current from 100 five-inch plates, the brick being supported by a funnel, which conducted the water into a vessel below. After a few months the brick near the negative pole of the battery was covered with crystals of carbonate of lime, and near the positive were formed crystals of arragonite. The same experiment being repeated with fluosilicic acid, regular hexahedral pyramids, similar in all respects, were obtained."

These experiments throw a flood of light on the nature of the power which operates on the particles of matter during the crystalline process,—the electric current of galvanic action forming crystals and disposing them according to their positive and negative qualities. From numerous facts, it would appear that the crystalline arrangement is produced by electrical attraction and repulsion. The various changes of circumstances produce among bodies an electrical change, so we observe the same circumstances produce a change in the crystalline form. Bodies mechanically mixed with each other in the first instance, will subsequently assume a crystalline form, and here it would seem that induction had taken place, the particles becoming polarized. In all the processes of crystallization a nucleus is formed, which draws the surrounding particles successively to it. This nucleus, which is often different from the external form of the crystal, being in a certain electrical state, in conformity to the laws of electrical attraction and repulsion, discriminately draws the other particles to it, consequently the formation of the aggregate crystal. And as the electrical state of the first formed nucleus, or the nucleus put in to hasten the process, is determined by its elementary constituents, and the nature of formation; hence the uniformity among bodies in their crystallized form under one circumstance, and the dissimilarity under the other, and why a nucleus of the same substance is the best excitant.

## ROBERTS' GALVANIC APPARATUS, USED FOR BLASTING.

Among the many recent gifts of science, the new method of blasting by means of electricity deserves especial notice. To miners and quarriers in particular, it offers the greatest advantages, in point both of economy and safety.

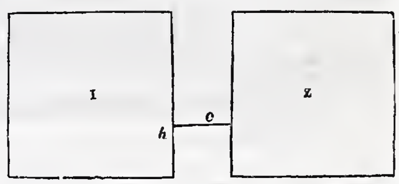
It may be stated that Mr Roberts' is not the first attempt to apply the principle to practice, viz., that a wire can be heated by electricity, and consequently ignite some kinds of inflammable substances, and among them gunpowder. It was done long ago by Franklin and others, by means of atmospheric electricity; but the extreme tendency of this kind of electricity to diffuse itself over everything in its vicinity, renders it at least inconvenient. Even a moist atmosphere is sufficient to convey the fluid away from whatever is charged with it, not to speak of the difficulty of getting it at all under such circumstances, which as far as is at present known, must for ever prevent its being applied practically in blasting. At a later period, Dr Hare, of Philadelphia, intimated that the current of the voltaic battery had not these disqualifications; but the mechanical arrangements which he introduced, were such as have hitherto prevented his plans from being carried into practice.

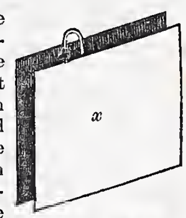
The simple apparatus of Mr Roberts is eminently adapted for the purpose intended; and the following description of it will not only enable any person to construct it, but also successfully to employ it when constructed.

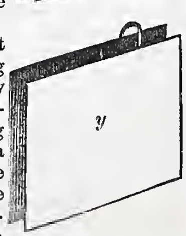
The apparatus consists of a battery, conducting wires, galvanometer, and cartridges.

In the description published by Captain Roberts several years ago, he proposes and describes a battery for the purpose, which is a modification of Daniell's, requiring sulphate of copper, porous diaphragms, &c., and is both troublesome to make, and inconvenient to use; at least, in operations which only require it to be in action for a few minutes at a time. He has, however, since obviated this difficulty by the invention of his *iron battery*, which is generally employed. This form of battery is shown in the figure annexed. The plates of it are 7 inches square, and 41 in number; 20 of zinc, and 21 of iron. The zinc plates are amalgamated, and this is done in the following manner:—

Into a shallow vessel, large enough to admit the plates being put flat into it, and touching the bottom, is poured a quantity of dilute sulphuric acid, with some mercury. A zinc plate is then put in, and the mercury rubbed over it, by means of a piece of cloth, fastened to the end of a rod of wood. When it is completely covered over with the mercury, the plate is gently wiped, and then dipped in clean water and carefully dried. The whole of the plates are thus treated, and should then be carefully handled, as they become very brittle, and break readily. 19 of the iron plates are soldered to copper wires, 3 inches in length, at the point *h*, one-third of the breadth of the plate. 19 zinc plates are soldered to the other ends of the wires, in like manner. 9 of these pairs of plates are bent at *c*, the middle of the wire downward, on a mandril of $\frac{3}{4}$ of an inch in diameter, and have the appearance as shown at *x*—the plates represented in shade, are the iron plates. The other 10 pairs are turned upside down, and bent downwards in the same manner, as shown by *y*.



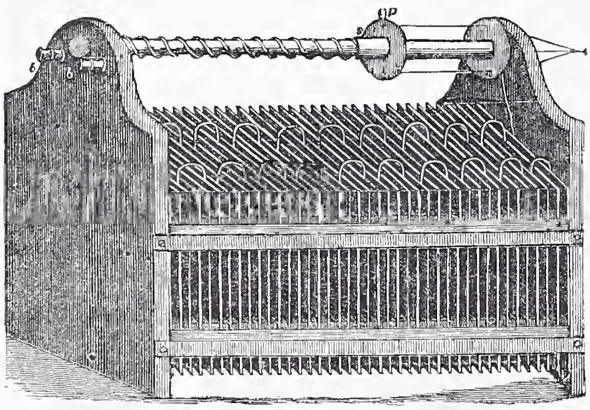




The use of their being turned different ways, is to prevent the wires from coming into contact, which they would do were they all bent over in the same way. To the single zinc plate which is left, only 19 being used, is soldered at the middle of the top, a copper wire. This plate is put between one of the *x*-turned pair of plates, and forms the negative pole of the battery. Next, between the two zinc plates is placed the iron

plate of one of the $y$-turned pair of plates; again, the iron plate of one of the $x$-turned pair is put in; then another of the $y$-turned pair of plates is inserted as before. Proceeding in this manner, the whole are arranged in such a way, that the last of the zinc plates has not an iron plate on either side of it. The two iron plates which are left—only 19 having been soldered to the zinc plates—are soldered to a piece of copper wire, and bent over in the manner of the $y$-turned pair of plates, and to the outer one is soldered a terminal copper wire, called the positive pole of the battery. Thus, there is an alternate series of zinc and iron plates, commencing with the first zinc plate, to which is attached the negative pole onwards to the last iron plate, to which is attached the positive pole. They are fixed in a frame, as represented in the figure. The ends of this frame are $8\frac{1}{2}$ inches broad, $\frac{5}{8}$ inches thick, and $11\frac{1}{2}$ in the extreme height. They are fixed firmly at the proper distance from each other, by two strips of wood on each side, $\frac{3}{4}$in. broad, $\frac{5}{8}$in. thick, and $11\frac{1}{2}$ in. in length. Two such strips are also placed at the bottom. They are all checked into the ends of the frame, and fastened with screws, the heads of which are covered with cement, to prevent their being acted on by the exciting solution.

The whole of the plates are then put into this frame, which is generally made of black birch or plane tree, and between every two plates are placed strips of wood (fir will do) resting horizontally on the tops of the cross bars to keep them from touching each other; their length is $8\frac{1}{4}$ inches, by about $\frac{1}{4}$ of an inch, varying according to the length of the frame, and the thickness of the plates. In general, the distance should be rather less, *and never more* than $\frac{1}{4}$ inch. The slips should be made so as to keep the plates firm in their places; for if they be loosely fitted, the zinc plates will be apt to be broken, being as was before stated, rendered *brittle by being amalgamated.* On the top of the frame is fixed a cylindrical rod of wood one inch thick; on this the discs are placed for connecting the poles of the battery. It also serves to lift the battery by. The discs are made of strong brass, three inches in diameter. In one of them $f$ is a

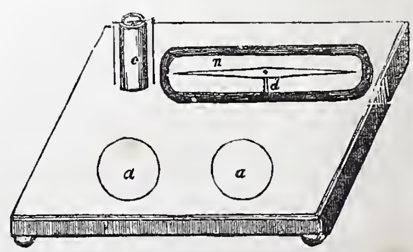


hole in the centre, made to fit the cylindrical rod tightly, so as not to move. In the other one $s$, the hole is made to fit a short tube of brass or tin plate, which moves freely along the rod, and serves to keep the disc steady. The disc is soldered to one end of this tube, and to the other end is attached a spiral spring of brass wire, a little greater in diameter than the cylindrical rod, and long enough to reach to the negative end of the battery, when the moveable disc $s$ is about three inches from the fixed disc $f$. To the disc $f$ is soldered the terminal copper wire of the positive pole of the battery. At the negative end of the battery, in the wood, and through it, are screwed two binding screws $b$ $b$; to one of these is soldered the end of the spiral spring, and to the other the terminal copper wire leading from the single zinc plate or negative pole of the battery. In the binding screws are two holes, one running transversely through it one-eighth of an inch in diameter, and the other from the end of it going into the transverse one. In this is put a *pinching screw,* so that if a wire were put into the transverse hole, it would be firmly fixed by the point of the pinching screw pressing it to one side of the hole.

In each of the two metallic discs are three small holes exactly opposite each other, and opposite these are holes in the end of the frame, so that a triple cord may pass through the wood. They are then passed through the fixed disc $f$, and through the sliding disc $s$. To this last, they are fixed by knots; the other ends of this triple cord are tied together at the distance of a few inches from the battery. It is represented in the diagram as drawn straight out. To this is attached a long cord or lanyard, by which to pull the discs together when standing at a distance from the battery. To prevent even the possibility of the discs touching each other when not required—which would be sometimes very dangerous—a hole is bored in the cylindrical rod, and a pin $p$ is put into it just before the sliding disc $s$; this is called the *safety pin.* The power of the battery depending in a great measure on the quality of the joinings, they should *always be made as perfect as possible.* The trough in which the battery is put, is twelve inches long, nine broad, and eight inches deep, three-fourth inch thick in material, and must be made water tight by cement.

The conducting wires are of covered copper wire, as thick as it is convenient to work with, and long enough to allow the battery to be out of danger from the fragments of rock that are thrown about at an explosion. About a hundred feet will in most cases answer the purpose, and in general it should be as short as the security of the battery will admit of. It is made as follows :—A length of two hundred feet of well-covered copper wire is cut into two equal parts, and laid side by side; the wires are then carefully covered with strong whipcord, beginning at about a foot from one end, and carried on to about the same distance from the other, where they are soldered to binding screws. The whole are then covered with shellac varnish, taking care that the holes in the binding screws are left clean, as also about an inch at the other end of the wire; the conductors are then ready for firing a single charge. But it is frequently required to fire several charges simultaneously; for it has been found that when two or three charges are fired at once, a much greater quantity of rock is rent, than when these charges are fired in succession. This is one great advantage of the new method of blasting, viz., that as many charges can be fired at once as are necessary, provided the battery has power enough to create the current, and the conducting wires are thick enough to convey it. It may be observed, that the power of the battery to ignite a *number* of charges depends upon the *size* of the plates, and its power to ignite any number at any considerable distance depends upon the *number* of plates; but the wire must be thick enough to convey the current, and the shorter it is the fewer plates within certain limits are required. In short, the conducting power of the wire is in direct proportion to its thickness, and is inversely proportionate to its length. When the battery has been found capable of firing a charge at a small distance, but is too weak to fire it at a greater distance, the intensity of the current must be increased by increasing the number of plates; but if it be sufficient to fire one cartridge at that distance, but not more, then the quantity of the current must be increased, by increasing the size of the plates. When it is wanted to fire several charges simultaneously, it is necessary to solder one binding screw on each wire wherever there is a bore in the rock, but care must be taken that neither the wire nor the binding screws touch each other in any place, except where they are soldered, for then the current would not pass to the cartridge, but would take, as it always does, the nearest way.

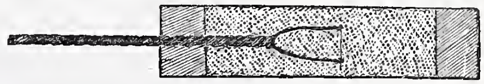
Before describing the cartridge, it is necessary to explain the galvanometer, as it is employed in the construction of them. It is well known, that a current of galvanism passing near a magnetic needle, causes it to turn to one side or the other. This simple apparatus is constructed on this principle. At the corner of the board, which is 9 inches long by 7 inches broad, is placed a small galvanic battery, consisting of a single pair of plates $c$, a copper cell 2 inches high, and 1 inch in diameter. To the bottom is soldered a copper wire which passes through the board. Inside of this is placed a zinc rod



½ an inch in diameter, and the same length as the copper cell. To the top of the rod a copper wire is soldered at the middle of its length; it is then bent downwards on each side, as shown in the figure, and goes also through the board. The zinc rod must be kept from touching the copper cylinder, by slips of wood or cork. *a a*, are two discs of brass plate, with a copper wire attached to each of them, also passing through the board. To the wire of the nearest disc is soldered the wire attached to the copper cell: *n* is a magnetic needle with brass cap in the centre, very delicately balanced on a steel point. Round this is fixed an oblong coil of insulated copper wire 4½ inches long, by 1½ inches in breadth, and of ten or twelve plies. The ends of this coil also pass through the board, and to one of them is connected the wire coming from the second disc; the other end being attached to the wire of the zinc rod. Thus there is a direct communication from the first disc to the copper cell of the battery, through the exciting solution to the zinc plate, then through the coil of wire around the needle to the second disc. Thus all that is wanted to complete the circuit, and consequently allow it to pass and effect the deflection of the needle, is metallic communication between the two brass discs. By this the quality of the cartridges is tested.

To make a cartridge, the copper wire employed must be well insulated with cotton or worsted thread. This wire does not require to be so thick as the conducting wires, and the length of it may vary according to the depth of the *bore* in the rock, which is commonly from 2 to 8 feet, so that 10 feet will likely answer most purposes. A length of twenty feet, then, is taken and doubled, and about one foot of it at the looped end is twisted round firm and closely like a rope. Having thus twisted together the wires to within an inch of the end, the bent part of the loop is cut off, and the ends or horns are straightened and placed parallel to each other, one quarter of an inch separate, and half an inch long. The extreme ends are then stripped of the thread, and with a file half the diameter of the wires is filed away, so that one side of them is flat. At an eighth of an inch from each end, the wires are doubled over, and a part of the fine steel wire is put into the hook so formed. The two surfaces of this hook are made to approach each other by a smart stroke of a hammer, thus completely fixing in good metallic contact the fine steel wire. This wire is called *balance wire* by the watchmakers who use it, and by whom it is sold on small bobbins, and is the only kind of wire that does well—all the other kinds should be discarded. Previous to joining the ends of the cartridge wires by means of the steel wire, they should be tried with the galvanometer, in case any part of the two wires are in contact with each other, which would altogether prevent the fine wire from becoming hot, by the current passing a nearer way.

The small battery of the galvanometer is charged with a solution of sulphuric acid and water, 1 part of the former to 25 of the latter. This is also the strength of solution with which the large battery is charged. The battery of the galvanometer is made very small—only of one pair of plates—on purpose that the steel wires of the cartridge will not only not be fused, but will not even be heated by its current, for if it should, the cartridge would be instantly exploded. If now the cartridge wires be placed on the discs *a a*, the battery being in action, and the coil of wire around the needle placed in the same line with it, the needle *n* should not be deflected because there should not be metallic communication between any part of the wires, but, when the steel wire is put on, and tried, the needle will instantly be deflected, showing that the junction of the wires are correct. The cartridge tubes to hold the powder close to the steel wire are of tinplate, three inches long by three-fourth inches in diameter, with its joint soldered air-tight. Cylinders of paper similar to the tin tubes, but not so long, are put inside of them to keep the horns of the conducting wires from touching the tin tube. The gunpowder is then prepared for the cartridge—it must be fine sporting powder; coarse powder will not do so well—and it is of essential importance that it be *perfectly* dry previous to its being put into the tube. Were this not attended to, the steel wire would be fused before the gunpowder would be dried. The drying can only be done with safety at a steam heat; for at a few degrees higher in temperature, ignition takes place. When a large number of cartridges is to be made, a steam bath should be used;—a small quantity can be dried in a plate that has been heated at the fire. The steel wires being fixed and tested by the galvanometer, the tin tubes are taken, the paper tubes put inside of them, the ends of the tubes are then closed by corks which have been divided lengthways into halves, thus forming two semi-cylinders; one of which being put into one of the ends of the tube, the cartridge wire is then placed above it, so that the steel wire will be nearly half way into the tube, the other half of the cork is then placed above the cartridge wire, and the whole is pushed into the tube, until the top of the cork be a little below the edge of the tube. The dry powder is then put into it by the other end, and this is closed up with a cork. Lastly, both ends are covered with cement to prevent the dampness from penetrating into the powder. The figure shows in



section the tin tube, part of the cartridge wires, the corks and the powder. The cement used for this purpose, as also for coating the joinings in the inside of the trough, is four oz. of bees' wax to nine oz. of resin, and a few drops of linseed oil are added; the ingredients are melted together in an iron ladle, and poured into the ends of the tubes; this cement sets readily, and is very tenacious. The cartridges should be always handled with care, as the steel wire is easily broken.

The apparatus having now been described, the method of applying it to blasting will easily be understood. Having made the hole in the rock of the necessary size, and cleaned it with oakum wadd, or other such stuff, freeing it from the loose sand, and also the dampness, one half of the charge is put into it, then the cartridge, and on the top of it is put the other half of the powder; the cartridge is thus in the centre of the charge. The powder should lie as loosely as possible together; a wadding, which may be either of straw or oakum, is then put down to the depth of three feet from the surface of the rock, and on this is put the tamping stuff; supposing the depth of the bore to be seven feet, and the charge to take up of this one foot, and the tamping stuff, as has already been stated, three feet, then there will be a space of three feet where there is nothing but atmospheric air. This arrangement has been found materially to increase the effect of the discharge.

The wadd being in its place, the hole is now filled up to the surface with *perfectly dry* sand. This curious property of a column of dry sand being capable of resisting almost any pressure without being forced out, is one, and not the least important, of the advantages of the new process. The fact has long been known, but has never been applied to any practical purpose till now in the *process of blasting by galvanism.*

Lastly. The cartridge wires are fixed to the binding screws upon the conducting wires; the other ends of which are taken to a place as safe as circumstances will allow, and are there attached to the binding screws *b b* of the battery. The trough is then filled up to the requisite height with the acid solution: the long cord tied to the end of the triple cord is then stretched in a line with the discs and spiral spring. The safety pin *p* being in its place and all ready, the person who is to operate puts the battery in the trough, takes out the safety pin, then goes to the end of the cord or lanyard, and draws it, bringing the two discs together, completing the circuit, when the steel wire in the cartridge will become hot, and ignite the powder of the charge.

The battery must now be removed from the trough, and dipped in clean water, to free it from the acid which is on the plates. Attention to this will preserve the battery for a much longer time than when it is neglected. The cartridge wires may then be taken from among the rubbish and fragments of rock, under which they will be found buried by the explosion. Previous to using the conducting wires at a charge, it is necessary to ascertain whether they are properly isolated from each other. This can be done in the same manner as the cartridges are tested; but it will require the large battery, as the current of the small one would be too feeble to go such a distance. It can be applied in the following way:—Into the binding screws *b b* put two pieces of copper wire; these are placed one on the zinc rod, and the other on the copper cell of the battery of the galvanometer, which thus, for the time being, acts as a connexion. The ends of the conducting wires being placed on the discs of the galvanometer, if the needle is not affected except when the binding screws at the other end of the wires are brought together, then it may be considered right; but if there are more binding screws on the conducting

wires than one pair, they should all be tried in this manner previous to using them.

In applying the apparatus in blasting under water, the conducting wires must be well covered by varnish, and the canister containing the charge should, of course, be perfectly water-tight. The mode of managing the apparatus is in every other respect the same as when employed in rock-blasting.

## ON THE MECHANICAL ARTS OF PERSIA.

By James Robertson, Esq.

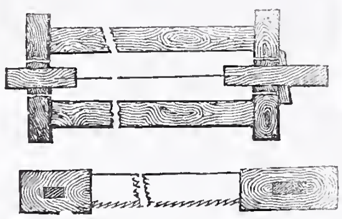
Although, perhaps, there is little to be gained in a practical point of view, from a description of the Persian arts, it may still be interesting to contrast our own highly improved manufactures with those of less advanced countries.

*Carpentry.*—The art of carpentry, as understood in this country, can scarcely be said to exist in Persia, the greatest efforts in this department being there confined to the construction of flat roofs of inconsiderable span; and this might be expected, from the circumstance of timber being there exceedingly scarce.

For forming roofs a species of poplar is generally employed, but for other purposes, oak, chestnut, plane, and the other kinds of hardwood are used. The hard timber, as sold in the bazars, is all of small scantling, as it has to be brought from the forest on the backs of mules or camels.

In accordance with the invariable custom of all Eastern artisans, the carpenter sits upon the ground while at work. Instead of a bench, a strong stake is driven down before him, leaving about 10 inches above the ground, and upon this he rests his work, and keeps it steady with his feet. The facility with which the work is executed, in such a disadvantageous position, has always been a subject of surprise to European workmen. In the royal arsenals, however, English tools are used, and a better system of working has been introduced, under the superintendence of British officers; but in the native workshops, the workmen are still to be seen squatted on the ground; and, when it is considered that they have been accustomed to this position from their infancy, and that their tools are of such a nature as to act with efficiency when used in this way, it is scarcely to be expected that any alteration in their mode of working could be effected by mere example.

One of the principal tools is the frame-saw. This is somewhat like the English pit-saw, but less in size, and it is used by drawing backward and forward; the timber being supported at one end. In using the hand-saw, the board to be cut up is placed against the stake already noticed, and kept steady with the foot; and as the teeth point backward towards the handle, the weight of the body assists in giving effect to the instrument. These saws are thin and light, as they have not to resist a thrust like ours. The adze is a most useful tool, and I have noticed English workmen in Persia using it in preference to the axe or paring-chisel for light work.

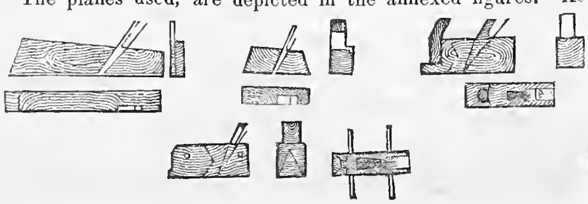


Frame-Saw.

Hand-Saw.

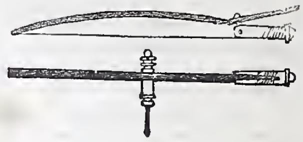
Adze.

The planes used, are depicted in the annexed figures. As the plane-irons have no covers, the planes are used across the grain of the wood.



The hammer is represented on the margin. The nail, instead of a head, has part of the thick end beat out thin, and this is turned over with the hammer as the nail is driven down. The bow and drill is a good instrument, and is used as a brad-awl, gimblet, and brace-and-bit.

Nail-hammer.



Bow and Drill.

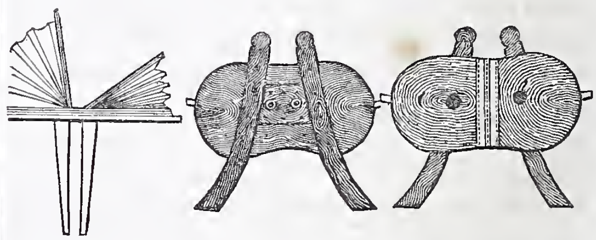
To this list many smaller tools might be added. Those represented, are drawn on a scale of one inch to the foot.

*Smithwork.*—As the work on which the Persian blacksmiths have to exert their skill is usually small, their tools are light and simple. The iron generally used is of Russian manufacture, which is brought from the ports of the Caspian sea, on the backs of mules. In the northern parts of Persia, malleable iron is manufactured directly from the ore; and this description of iron has been long esteemed for making excellent horse-shoes, and horse-shoe nails.

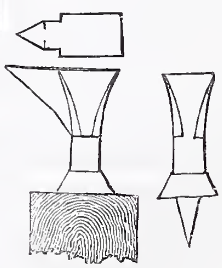
As coal is almost unknown in Persia, the fuel used by the smiths is entirely charcoal prepared from hard wood. The smiths stand when the work requires to be heated, but in finishing, or making small articles, they sit on the ground.

The hearth is a small platform, without a chimney, having a low wall on one side, to prevent the bellows being injured by the heat.

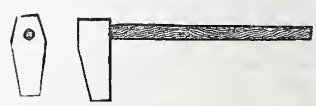
The bellows are double, and the two nozzles enter the twyre



together. They are worked by a man, who stands between the handles, and by his pushing forward and drawing back the handles alternately, a steady blast is produced. The anvil, hammer,



Anvil.

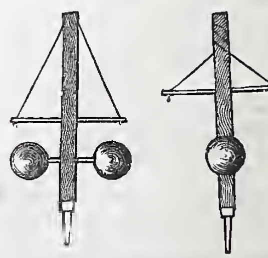


Hammer.

Tongs.

and tongs, require no explanation more than the drawings supply.

The drill is sometimes made of wood, and sometimes of iron, and works remarkably well, notwithstanding its quick motion: it is worked by depressing the small bar, which reascends at every stroke. A similar instrument of smaller size is used in this country in die-sinking.



The Drill.

The anvil, hammer, tongs, and drill, are shown upon a scale of one-twelfth. The bellows are shown upon a scale of one twenty-fourth.

*Turning in Wood.*—This operation is performed by a carpenter

while sitting on the ground. Two stakes are driven down before him, a short distance apart, and an iron spindle, with a small drum attached, revolves between them. The spindle is passed through the wood which is to be turned, and with the assistance of a bow and string passed round the drum, the spindle is made to revolve rapidly. The bow is worked backward and forward by the left hand, while the right holds the cutting-tool supported on a block of wood. Turning in metal is almost unknown.

*Stone Cutting.*—As the buildings are generally made of clay or brick, stone-cutting is little practised in Persia. Gravestones, millstones, and a few other articles, therefore, embrace the whole of the works of this description. When the work admits of it, the stone-cutters sit upon the ground. The principal tools are, small double-pointed picks, and mason irons resembling large nails, some pointed, and some chisel-shaped. With these tools the stone-cutters work very slowly, and it is only after immense labour that they succeed in bringing a hard stone to the required form.

For boring in stone, the instrument is an iron rod steeled at the end, but instead of a chisel point the end is cut flat off. Two parallel regular grooves are cut deep across this face, and these are intersected by three others at right angles, thus dividing the end of the rod into twelve compartments. While boring, the hole is kept full of water, and while the rod is turned round gradually with the left hand, the blows are struck by a small hammer held in the right. This method of boring is very tedious.

There are two descriptions of corn-mills, the hand-mill and the water-mill. The first is composed of two small circular stones, which are kept together by a peg in the centre of the lower stone, which passes through a large opening in the upper one; the grain is fed in at this opening, and while the upper stone is turned round by means of a small peg on its rim, the flour is thrown out at the edges.

For moving the large stone of the water-mill a considerable fall is required. A hollow tree is placed in a sloping position, from the end of the lead, and the confined water, in rushing from the lower orifice, acts upon the oblique and narrow float-boards of a horizontal wheel, about five or six feet in diameter. A perpendicular iron spindle passes from the water-wheel through the lower stone, and gives motion to the upper one, without any intermediate machinery. These mills are placed on the slopes of hills when water can be commanded; and as they are generally protected by a fortified tower, and surrounded by a luxuriant grove of tall poplars, they form a pleasing feature of the landscape on approaching a Persian village.

*Method of Procuring Water.*—As rain seldom falls in Persia the farmers have recourse to irrigation for watering their fields. The water used in this process is procured either by means of cuts from the rivers in the vicinity, or more rarely by a system of subterranean canals, which draw off the water from the high grounds. From a want of concert among the inhabitants, the water-courses are seldom carried to any distance; so that immense plains of the richest alluvial soil are met with along the banks of most rivers, which, by a little capital and skill, could be made capable of yielding the richest crops, but which at present afford only a transient pasturage for the herds of the wandering Coords. This is more particularly the case when the rivers afford little fall in their course, as the limited capital of the people precludes any attempt to conduct a canal along an extended district, or the erection of machinery to raise the water even to an inconsiderable height. As far as I know, the celebrated Persian wheel is now unknown in the country from which it derived its name; nor is there any hope of foreigners introducing a better system where property is so insecure. It must be admitted, however, that the inhabitants show no want of ingenuity or enterprise, when they see clearly the advantages of any undertaking suited to their limited means; and this is strikingly displayed in their mode of procuring water in the populous districts. They sink a series of small shallow shafts in the thick alluvial clay, and connect the pits by means of small mines or levels. A subterranean canal is carried in this way from the flat ground till it meet the slope of the surrounding hills. At this point a cross mine is driven along the face of the hard strata, and numerous small openings are made into the rock, wherever the water makes its appearance. Very considerable streams are often procured in this way, which gush from their hidden sources in a profuse current, after travelling several miles below ground, protected in their course by the clay cover from being evaporated by the overpowering heat of the sun. In travelling through the plains of Persia, immense rows of small hillocks may everywhere be seen, marking the position of these pits and the lines of the old canals, in districts now quite deserted; and these at once show the extent to which this system had at one time been carried, and the wretchedness to which the country has now been reduced.

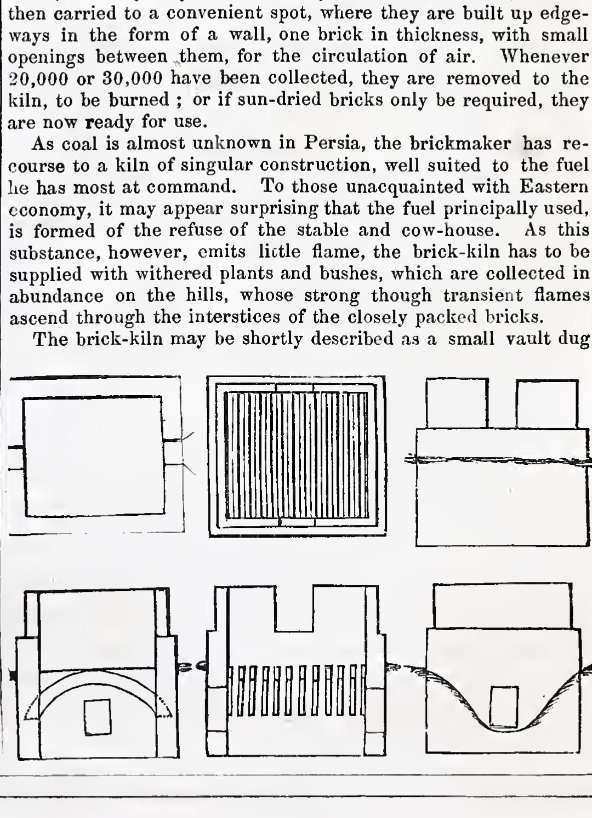
*Brick-Making.*—A level space of ground having been selected, near a stream of water, the grass and vegetable soils are carefully removed. The ground is then broken at one extremity of the prepared platform, and the easily pulverized clay is carefully passed through a small meshed riddle, and placed in the hollow, while the stones and roots are thrown behind. When a sufficient quantity of riddled clay has been collected, a small stream of water is allowed to flow into the hollow, and the mass is brought to a proper consistency by treading. The prepared clay is now deposited in different small heaps upon the floor, which has been previously spread with finely riddled earth. The moulds are formed of thin wood, without any of those projections or handles which are seen in this country. For the common-sized brick, the mould is formed about 9 inches square, and $1\frac{1}{2}$ inch deep; but larger bricks are sometimes required, for paving courts and coping walls for which another mould is necessary.

The mould is placed on the ground, and the brickmaker takes a part of the clay in his hands, and places it loosely in the mould. He then dips his hand in water and throws a little of it around the inside of the mould, to prevent the clay from adhering to the wood. By a peculiar action of the hands, the clay is then drawn from the middle and pressed firmly into the corners and round the sides of the mould, and the whole is afterwards levelled over, by a dexterous diagonal stroke of the right hand. The mould is now lifted off the brick, and placed to the right hand side, close to, and in the same line with, the brick already formed, and it is again filled up in the same way. Thus he proceeds, frequently washing the mould in water, till a straight line of bricks has been laid down, of many yards in length; a second line is then commenced, exactly the thickness of the mould from the first, and the whole ground is finally covered with closely arranged rows of bricks.

In two days or more, when the level space has been covered, the first-made bricks become sufficiently dried to be handled, and the brickmaker now proceeds to place them upon edge in lines; in a day they are sufficiently hard to be removed, and are then carried to a convenient spot, where they are built up edgeways in the form of a wall, one brick in thickness, with small openings between them, for the circulation of air. Whenever 20,000 or 30,000 have been collected, they are removed to the kiln, to be burned; or if sun-dried bricks only be required, they are now ready for use.

As coal is almost unknown in Persia, the brickmaker has recourse to a kiln of singular construction, well suited to the fuel he has most at command. To those unacquainted with Eastern economy, it may appear surprising that the fuel principally used, is formed of the refuse of the stable and cow-house. As this substance, however, emits little flame, the brick-kiln has to be supplied with withered plants and bushes, which are collected in abundance on the hills, whose strong though transient flames ascend through the interstices of the closely packed bricks.

The brick-kiln may be shortly described as a small vault dug



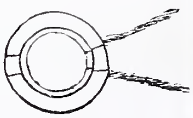
out of the ground, and surrounded by a wall of sun-dried brick, having a door-way at each end for receiving the fuel. It is closely covered by a series of very narrow arches, the top of which forms the floor on which the bricks are placed; and this again is surrounded by a brick wall, with door-ways for putting in and removing the bricks. The bricks are arranged on edge in the kiln, and the door-ways are built up. A regular supply of fuel is kept up, by the two lower doors, until the required quantity has been consumed. During the first two or three hours, clouds of white vapour ascend from the top of the kiln. When this appearance has ceased, and thick volumes of dark smoke begin to arise, two or three layers of unburnt bricks are laid flatways over the top of the kiln. In about twelve hours the whole of the fuel has been thrown into the vault, and the two feeding door-ways are built up. The kiln is allowed to remain in this state for two or three days, and, when perfectly cool, the burnt bricks are removed for use.

The bricks, when well prepared, are of a fine red colour, and of considerable hardness; but, from the mode of manufacture, one side is always exceedingly rough and uneven, but this is no disadvantage, as the joints in buildings are seldom less than one inch and a half thick.

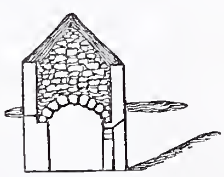
It may become a question whether the method above described might not be successfully imitated in our own country, particularly in those inland and secluded districts where coal is dear, and yet where a demand exists for tiles and bricks for agricultural and other purposes.

It is difficult to compare the Persian process with our own; but it may be noticed, that, in this country, a workman can mould about 700 paving tiles in a day, of exactly the same dimensions as the Persian bricks, but then the clay is prepared by machinery, and the moist tiles are removed by other hands. The price of these tiles, when made of common clay, is £5 per 1000. A Persian will prepare the clay and make about 2000 per day, and the selling price is only 9s. per 1000; but it need scarcely be remarked that the bricks are of very inferior workmanship.

*Lime-burning.*—The kiln is constructed in the following manner:—A circular excavation, of about ten feet diameter, and six feet deep, is made in the ground in a dry situation, and a sloping pathway cut down to the bottom on one side. A circular wall of rubble stone, two feet in thickness, is then built round the interior of the excavation. At five feet from the foundation, a scarcement of six inches is left in the inside, and the wall, thus diminished, is carried up six feet higher. A small door-way is left opposite the path, and another small opening immediately above it. A narrow door-way is also left in the upper part of the wall, but on the opposite side.



In charging the kiln a layer of limestone is first laid all round the scarcement, each piece projecting a little inward, and these are firmly packed and wedged together. A second layer, of larger pieces, is then laid over the first, which also projects inward beyond the first course; a series of similar courses succeed, each being of less diameter than the preceding, the whole forming a dome-shaped ceiling of limestone, which is closed by a single stone at the top. Great attention is required, during the filling up, that the larger masses of limestone may be laid lowest and nearest the centre, and the smaller pieces towards the wall and upper part of the kiln. The door-way, in the upper part of the wall, is now built up, and a conical hill of chips thrown on the top of the broken limestone, in the kiln, and it is now ready for being lighted. A sufficient quantity of furze or withered bushes having been collected, near the kiln, the workman throws gradually, through the feeding aperture, so many loads of fuel as he judges necessary, to calcine the limestone. When the white vapour and smoke disappear, then a quantity of lime-riddling, ashes, or other refuse, is spread over the top of the kiln, and the feeding door-way built up. The kiln remains in this state for two or three days, and is then emptied by opening the upper door-way, and removing the burned limestone, including the stones used in forming the dome. The ashes are used in the manufacture of soap,



With a few improvements, this kiln might be used economically for burning lime, where peat is abundant, and even in most large farms in this country, as much wreck and clippings are burned on the ground every year as would be sufficient for calcining several kilns of limestone in this simple manner.

Almost all the buildings in Persia are constructed either of clay or bricks.

*Clay-Building.*—The clay is generally procured near the intended erection, and is brought to the proper consistency by mixing with water and treading with the foot. For walls, a foundation is cut out as far down as the vegetable mould, and this trench is filled up with small stones and clay. The walls are built in courses, of about one yard in thickness, each course being allowed sufficient time to consolidate before another is laid. The workman stands upon the top of the wall, and being supplied with pieces of clay by an assistant below, he elevates his arms and throws the mass forcibly down, and then treads the pieces more firmly together with his feet.

The layers are brought to the required batter, and smoothed on the outside, by means of a flat cutting spade. The heat and extreme dryness of the climate, soon render a wall of this description hard and firm, and they last a very long time, as rain seldom falls. Most Persian villages are surrounded by high walls of this kind, having flank towers at every angle, and a rude ditch in front, from which the materials were excavated, and even the fortifications of the principal cities are constructed of the same material. Almost all the houses are also built in this way, and it is only when room is valuable that thin partition-walls are erected of bricks.

*Brick-Building.*—Of this there are two kinds,—building with sun-dried brick, and with kiln-dried brick; the method of building, however, is much the same for both. The mortar is generally clay, mixed with chopped straw, and sometimes containing a small proportion of lime. While building, the workmen do not use a trowel, but lay the mortar with the hand. The bond is simple, as the bricks are square, and do not admit of much variety of arrangement. The mortar-joints are usually from one to two inches thick and very irregular, unless in arches or doorways, when a good deal of neatness is often exhibited. As timber is very scarce, brick-arches and domes are common. The semicylindric arched roof is built in this way; after the side walls and gables of the space intended to be covered have been erected, the curve of the arch is marked out upon one of the gables, and this is plastered over with the common clay-mortar—a layer of brick is then stuck upon the mortar—and as the bricks are thin and light, they remain firm till the ring is completed, and then small chips are pinned into the joints at the opening ends. When one layer is finished, it is plastered over with mortar, and a second layer is stuck upon it in the same manner. In this way an arch of any required length, and of considerable span, is quickly constructed, *without centering.* If the bricks were made sufficiently thin and light, this mode of building would answer well in this country for arching tunnels and drains, and for mining purposes.

Large spaces are often covered over by a brick-dome, or by a series of domes supported on pillars. The pillars being built, thin arches are thrown, with the assistance of a slight centering, from pillar to pillar, thus dividing the space to be covered, into square compartments. The domes are then completed in the way described for the common arch, without centering, the workmen placing layers of brick on the four sides, alternately. These layers get shorter and shorter as the work proceeds towards the centre, and the workmen, judging by his eye alone, gives the whole intrados such a curve as to form a neat dome when completed. When the domes are very large, stucco is used as mortar, and the bricks, instead of being placed on edge, have their faces downward, and their edges joined together by the cement.

For light walls, hollow building is common. The first course is of one brick on bed; in the second, two rows of bricks are placed on edge, forming the two faces of the wall, and an upright brick is placed across at every joint; the third course is brick on bed again, and so on. This kind of building would answer well in this country for the upper parts of garden-walls, and generally for building when strength is not required.

The roofs of dwelling-houses are commonly flat, and formed of poplar-trees, neatly peeled—small laths are placed across the beams, and a coarse mat, made of reeds, is placed on the top; a

layer of furze is laid over the mat, and the whole is covered by a considerable thickness of clay; the top of the clay is gently sloped, and rendered impervious to water, by being coated repeatedly with clay and chopped straw.

In the houses of the wealthy, the roof is lathed and plastered in the inside, and often beautifully painted and gilt.

The walls of inferior houses are plastered with clay and chopped straw, which has a neat clean appearance; while the apartments of the rich are beautifully finished with stucco, which is either left plain, or decorated with gilding and painting.

It is unnecessary here to narrate the arrangement of Persian houses, as good descriptions of these are to be met with in the works of recent travellers; and the writer has throughout limited his observations to such processes as have not been hitherto noticed.

## DOUBLE SCREWING MACHINE.

By Messrs. Randolph, Elliot and Co., Glasgow.

Fig. 1 is a side elevation of the machine; fig. 2 is a plan; fig. 3 is an elevation of the end at which nuts are screwed; and fig. 4 an elevation of the bolt-screwing end. The framework of the machine I I, and the sole plate A A, are one casting. The cone has three speeds for receiving and communicating motion by the pinion G, of fifteen teeth on its spindle. This drives the wheel D, of fifty-six teeth, fixed on the smaller screwing spindle s. On the same spindle is keyed the pinion F, of eighteen teeth driving

*Fig.* 1.

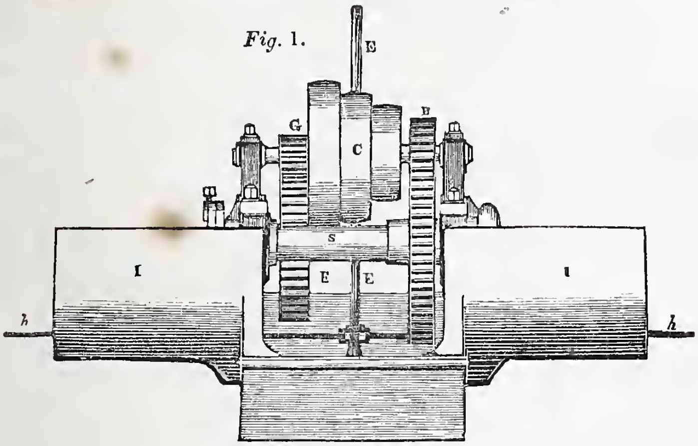
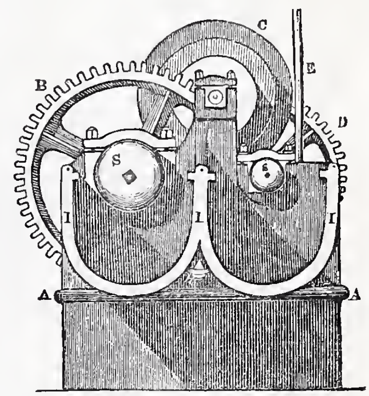



*Fig.* 3.




the wheel B of seventy-two teeth, keyed on the larger screwing spindle S. These spindles are hollow. In fig. 3 the chucks are shown, with square recesses to receive the heads of taps for screwing nuts. In fig. 4, there are recesses large and small in the plates *t t*, to receive dies, and pinching pins to hold them. By these, bolts and other rods requiring outside screwing are executed. *h h* are opposite ends of a handle for stopping and reversing the motion of the spindles at either end of the machine.

*Fig.* 2.

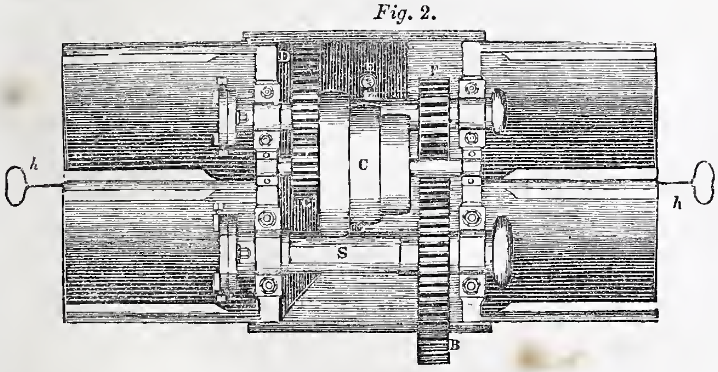
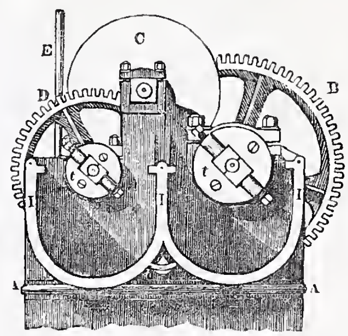


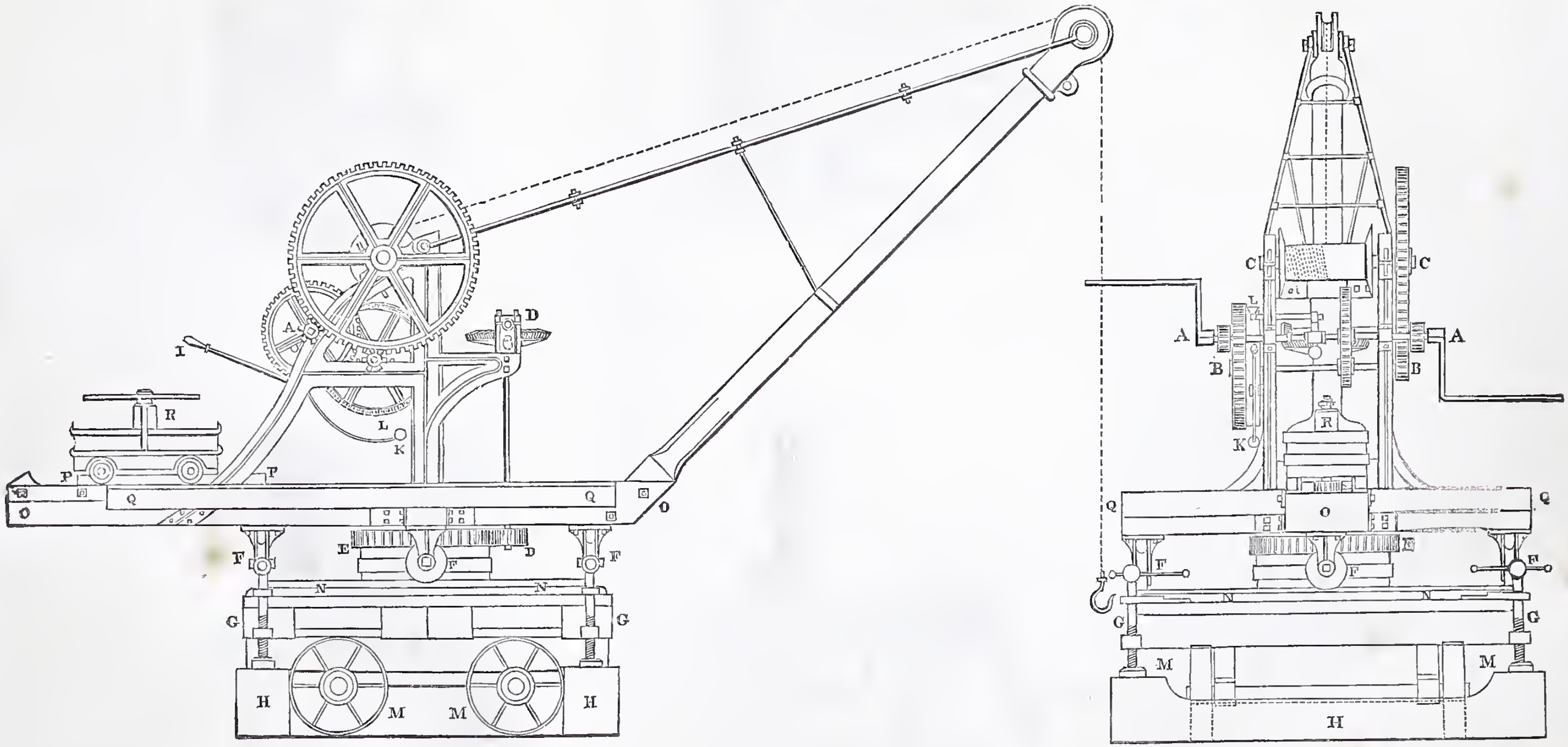

*Fig.* 4.




They are connected with the upright rod E, by a lever, which has a neighbour near the upper end, which works a traversing rod, on which are fixed the shifting forks, working an open and cross belt. In figs. 3 and 4 are shown the projecting planed strips on which the bolt and nut-holders are carried during the operation of screwing.

The top gearing consists of a fast pulley, with a loose pulley on each side of it. These are all upon the same shaft, with a cone of three speeds similar to C—the last carries the driving-belt communicating directly with the machine. The pulleys are of different breadths: the fixed one being narrower than either of the two loose ones. These last carry the driving-belts when the machine is not at work. When it is to be put in operation, one of the belts—the cross or open one—is passed upon the fixed pulley by means of the forks upon the upper traversing rod, which is commanded by the handles *h h*.

## PORTABLE BALANCE CRANE.



A, the first shaft, on each end of which a handle is fitted. On this shaft there are fixed one wheel, two feet diameter, and two pinions, each six inches diameter. B, the second shaft; on it are fixed two wheels, one foot, and two feet six inches respectively, and a pinion six inches diameter. C, is the barrel shaft, having on it the barrel nine inches diameter by two feet long, and a wheel four feet diameter. This four-feet wheel, and the two-and-a-half-feet wheel, are intended to gear with the pinions on the first shaft and second shafts, and the two feet and one foot wheels on these shafts also work together. By these wheels, then, three different powers are had for the more economical working of the crane, and, accordingly, the first shaft, by moving laterally, has three positions, in which it is held by a pall. L, the friction strap and wheel, I, the handle, K, the counter-weight. F F F F, four pulleys fixed in brackets to the platform Q Q of the machine, which is eleven feet by eight feet nine inches. The pulleys run on the race course N N, which is bolted down to the frame G G, which has four setting screws at the corners for levelling the machine. These screws operate on two blocks H H, placed on the ground, and raise the crane off the wheels M M. D D, upright shaft, on which is fixed at the upper end a bevil wheel, wrought by a pinion on a horizontal shaft, which is turned by a handle. On the under end is a spur pinion of six inches diameter, in gear with a three-feet wheel fixed on the frame G G, and concentric with the post; thus, by turning the handle, the crane turns on its centre. R, the balance-weight, which is wrought to and from the centre of the crane by a pinion working in the rack P P. O O, two main beams, to which the gib and the crane cheeks are bolted. This crane is intended to raise seven tons, and is especially useful in its capability of reaching situations inaccessible to fixed cranes, and where these might be inconvenient. The River Clyde Trust have had several constructed for general use at the Broomielaw; and, we believe, Messrs Maudsley and Field of London, have one in their works, of the same character.

## TABLE OF THE STRENGTHS OF DIFFERENT SORTS OF TIMBER.

This Table contains the results of five different series of experiments upon the strength and qualities of different sorts of useful Timber. The experiments are detailed at considerable length in Vol. V. of the Professional Papers of the Royal Engineers. The names of the Experimenters are given at the the top of the Columns in which the mean results of their experiments are contained. The transverse strength S is calculated from the common formula $\frac{W\,l}{4\,ad^2}$ in which W is the weight in lbs. necessary to break a beam of $l$ length, $a$ breadth, and $d$ depth, and supported at the ends; or S may be taken as the resistance of a rod an inch square.

| Names of Woods. | OBSERVERS: LT. NELSON. sp. gr. | S. | CAPT. YOUNG. sp. gr. | S. | MR. MOORE. sp. gr. | S. | MR. BARLOW. sp. gr. | S. | LT. DENISON. sp. gr. | S. | Mean. sp. gr. | S. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| frican Oak | 985 | 2484 | . . | . . | 962 | 2522 | 982 | 2493 | 1024 | 2595 | 988 | 2523 | Sp. gr. 777 when dry |
| sh, English | . . | . . | . . | . . | . . | . . | 760 | 2026 | . . | . . | 760 | 2026 | |
| ,, American | 611 | 1550 | . . | . . | . . | . . | . . | . . | 642 | 2041 | 626 | 1795 | |
| ,, ,, Swamp | . . | . . | . . | . . | . . | . . | . . | . . | 925 | 1165 | 925 | 1165 | |
| ,, ,, Black | . . | . . | . . | . . | . . | . . | . . | . . | 533 | 861 | 533 | 861 | |
| Beech, English | . . | . . | . . | . . | . . | . . | 696 | 1556 | . . | . . | 696 | 1556 | |
| ,, American White | . . | . . | . . | . . | . . | . . | . . | . . | 711 | 1380 | 711 | 1380 | |
| ,, ,, Red | 778 | 1720 | . . | . . | . . | . . | . . | . . | 772 | 1758 | 775 | 1739 | |
| Birch, Common | . . | . . | . . | . . | . . | . . | 711 | 1928 | . . | . . | 711 | 1928 | |
| ,, American Black | 682 | 1848 | . . | . . | . . | . . | 649 | 1810 | 679 | 2525 | 670 | 2061 | |
| ,, ,, Yellow | . . | . . | . . | . . | . . | . . | . . | . . | 756 | 1335 | 756 | 1335 | |
| Cedar, Bermuda | 748 | 1395 | . . | 1491 | . . | . . | . . | . . | . . | . . | 748 | 1443 | |
| ,, Gaudaloupe | 756 | 2044 | . . | . . | . . | . . | . . | . . | . . | . . | 756 | 2044 | |
| ,, American White | . . | . . | . . | . . | . . | . . | . . | . . | 354 | 766 | 354 | 766 | |
| ,, of Lebanon | . . | . . | . . | . . | . . | . . | . . | . . | 330 | 1493 | 330 | 1493 | |
| Elm, English | . . | . . | . . | . . | . . | . . | 553 | 1013 | 605 | 551 | 579 | 782 | |
| ,, Canada Rock | 700 | 1869 | . . | . . | . . | . . | . . | . . | 751 | 2072 | 725 | 1970 | |
| Hiccory, American | 871 | 1672 | . . | 2447 | 786 | 2192 | . . | . . | 836 | 2205 | 831 | 2129 | |
| ,, ,, Bitter Nut | . . | . . | . . | . . | . . | . . | . . | . . | 871 | 1465 | 871 | 1465 | |
| Oak, English | 834 | 1629 | . . | . . | 816 | 1919 | 934 | 1672 | 733 | 1556 | 829 | 1694 | |
| ,, American White | 645 | 1699 | . . | . . | 836 | 1699 | 872 | 1766 | 772 | 1809 | 779 | 1743 | |
| ,, ,, Red | 940 | 1709 | . . | . . | . . | . . | . . | . . | 964 | 1665 | 952 | 1687 | |
| ,, ,, Live | 1160 | 1862 | . . | . . | . . | . . | . . | . . | . . | . . | 1160 | 1862 | |
| ,, Adriatic | . . | . . | . . | . . | 718 | 1559 | 993 | 1383 | . . | . . | 855 | 1471 | |
| ,, Dantzic | . . | . . | . . | . . | 684 | 1579 | 756 | 1457 | . . | . . | 720 | 1518 | |
| ,, Italian | . . | . . | . . | . . | 796 | 1688 | . . | . . | . . | . . | 796 | 1688 | |
| ,, Lorraine | . . | . . | . . | . . | 796 | 1483 | . . | . . | . . | . . | 796 | 1483 | |
| ,, Memel | . . | . . | . . | . . | 727 | 1665 | . . | . . | . . | . . | 727 | 1665 | |
| Pine, American White | 453 | 1456 | 410 | 1073 | . . | . . | . . | . . | 432 | 1160 | 432 | 1229 | |
| ,, ,, Red | 621 | 1944 | . . | 1799 | 521 | 1289 | 657 | 1341 | 506 | 1261 | 576 | 1527 | |
| ,, ,, Yellow | . . | . . | . . | . . | 516 | 1188 | 553 | 1102 | 456 | 1266 | 508 | 1185 | |
| ,, ,, Pitch | . . | . . | . . | . . | . . | . . | 660 | 1632 | 820 | 1822 | 740 | 1727 | |
| ,, Virginia | . . | . . | . . | . . | 590 | 1456 | . . | . . | . . | . . | 590 | 1456 | |
| ,, Archangel | . . | . . | . . | . . | 551 | 1370 | . . | . . | . . | . . | 551 | 1370 | |
| ,, Dantzic | . . | . . | . . | . . | 649 | 1426 | . . | . . | . . | . . | 649 | 1426 | |
| ,, Memel | . . | . . | . . | . . | 601 | 1348 | . . | . . | . . | . . | 601 | 1348 | |
| ,, Prussian | . . | . . | . . | . . | 596 | 1445 | . . | . . | . . | . . | 596 | 1445 | |
| ,, Riga | . . | . . | . . | . . | 562 | 1687 | 746 | 1079 | . . | . . | 654 | 1383 | |
| Spruce | . . | . . | . . | . . | 503 | 1346 | . . | . . | . . | . . | 503 | 1346 | |
| ,, American | . . | . . | . . | . . | . . | . . | . . | . . | 772 | 1036 | 772 | 1036 | |
| Mar Forest Fir | . . | . . | . . | . . | . . | . . | 698 | 1232 | . . | . . | 698 | 1232 | |
| Norway Spar | . . | . . | . . | . . | . . | . . | 577 | 1474 | . . | . . | 577 | 1474 | |
| Deal, Christiana | . . | . . | . . | . . | . . | . . | 689 | 1562 | . . | . . | 689 | 1562 | |
| Canada Balsam | . . | . . | . . | . . | . . | . . | . . | . . | 548 | 1123 | 548 | 1123 | |
| Hemlock | . . | . . | . . | . . | . . | . . | . . | . . | 911 | 1142 | 911 | 1142 | |
| Larch | . . | . . | . . | . . | 658 | 1958 | 542 | 995 | 468 | 1052 | 556 | 1335 | The specimen tried by Mr. Moore probably a different kind of timber. |
| ,, Americn or Tamarak | . . | . . | . . | . . | . . | . . | . . | . . | 433 | 911 | 433 | 911 | |
| Lignum-Vitæ | 1082 | 2013 | . . | . . | . . | . . | . . | . . | . . | . . | 1082 | 2013 | |
| Mahogany, Nassau | 812 | 1752 | . . | 1904 | 525 | 1503 | . . | . . | . . | . . | 668 | 1719 | |
| Mangrove, Bermuda Black | 1188 | 1699 | . . | . . | . . | . . | . . | . . | . . | . . | 1188 | 1699 | |
| ,, ,, White | 951 | 1985 | . . | . . | . . | . . | . . | . . | . . | . . | 951 | 1985 | |
| Teak | 719 | 1898 | . . | . . | 723 | 1964 | 745 | 2462 | . . | . . | 729 | 2108 | |
| Poon | . . | . . | . . | . . | 768 | 1687 | 579 | 2221 | . . | . . | 673 | 1954 | |
| Acacia | . . | . . | . . | . . | . . | . . | 710 | 1867 | . . | . . | 710 | 1867 | |
| Sneezewood | 1066 | 3305 | . . | . . | . . | . . | . . | . . | . . | . . | 1066 | 3305 | S. Africa. |
| Yellow-wood | 926 | 2103 | . . | . . | . . | . . | . . | . . | . . | . . | 926 | 2103 | W. Indies. |
| Greenheart | . . | . . | 970 | 2471 | . . | . . | 1000 | 2759 | . . | . . | 985 | 2615 | |
| Wallaba | . . | . . | 1147 | 1643 | . . | . . | . . | . . | . . | . . | 1147 | 1643 | |
| Bullet Tree | . . | . . | 1075 | 2733 | . . | . . | 1029 | 2651 | . . | . . | 1052 | 2692 | |
| Kakarally | . . | . . | 1223 | 2379 | . . | . . | . . | . . | . . | . . | 1223 | 2379 | Demerara. |
| Crab-wood | . . | . . | 648 | 1875 | . . | . . | . . | . . | . . | . . | 648 | 1875 | |
| Locust | . . | . . | . . | . . | . . | . . | 954 | 3430 | . . | . . | 954 | 3430 | |
| Cabacally | . . | . . | . . | . . | . . | . . | 900 | 3518 | . . | . . | 900 | 2518 | |

## STRAIGHT AND CIRCULAR PLANING-MACHINE.

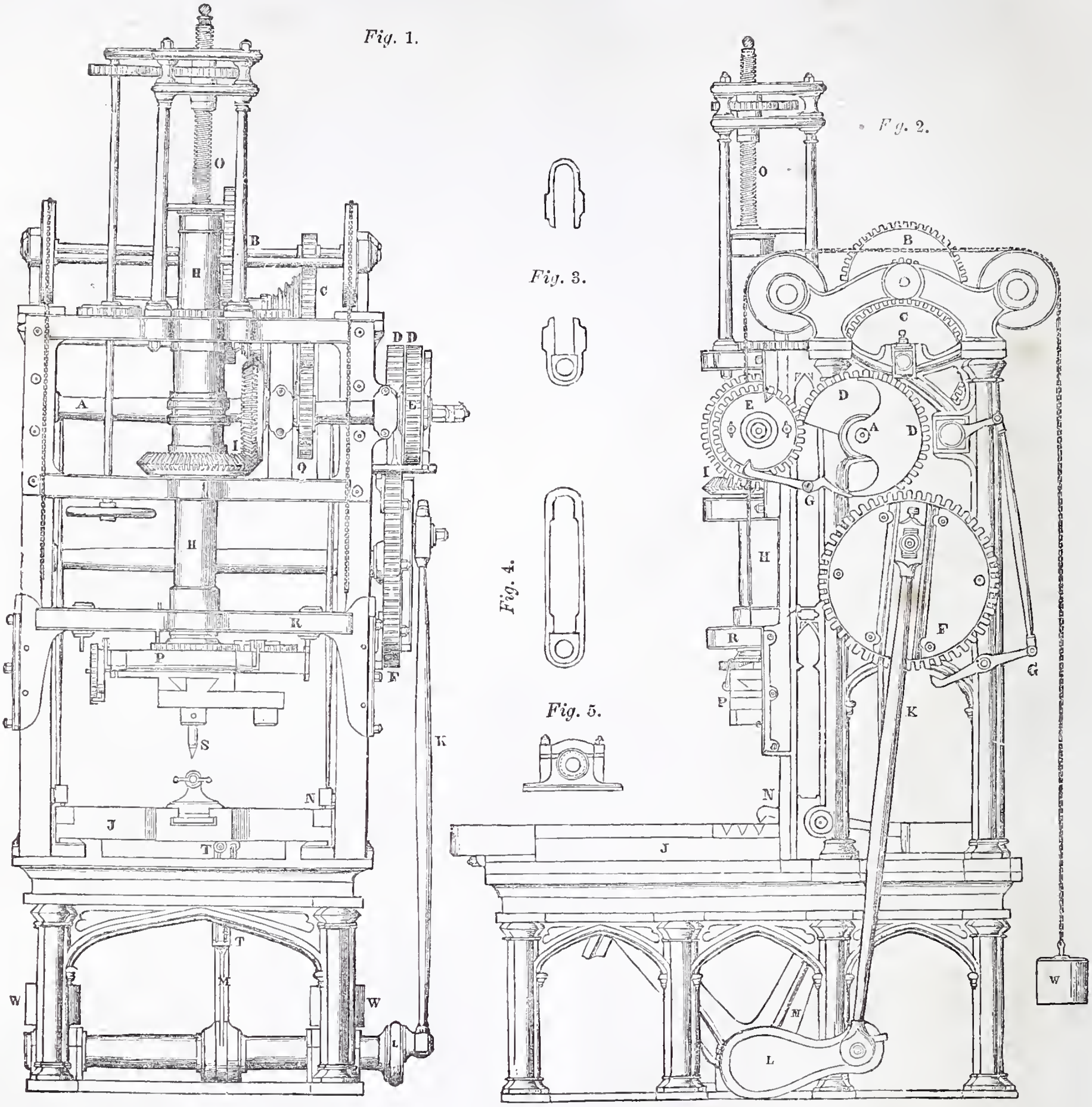



Fig. 1 is a front elevation; fig. 2 is a side elevation. A A is a shaft driven by the double-speed gear B C, in which the driving cone is seen beside the wheel at C, which drives a wheel keyed on the shaft A, on which are also keyed two toothed sectors D D, so adjusted as to drive the wheels E F on different shafts alternately, giving them each half a revolution, these wheels in the intervals being held by the detents G G. The wheel E drives the mitre wheels I, and through them the spindle H, giving it a revolving motion, and thus doing the circular work. Diametrically across the wheel F a groove is cast, in which the bush of the connecting-rod K is adjusted to any distance from the centre, and thereby causing the table J to traverse the necessary distance by the crank L and sector M on the same shaft, connected to the table by chains, which are seen at T, fig. 1. The detent N holds the table while the circular portion of the work is being done. The screw O tempers the height of the spindle. The double slide P adjusts the cutter S to the proper distance from the centre.

If a continuous circular motion be wanted, the sectors D D are withdrawn, and the wheel Q set in gear with the shaft A. This motion is adapted for boring and facing.

W W are counterweights against the spindle and the sliding bracket R.

Fig. 3 is a common form of bush straps.

Fig. 4 is another form, which can be completely finished by this machine.

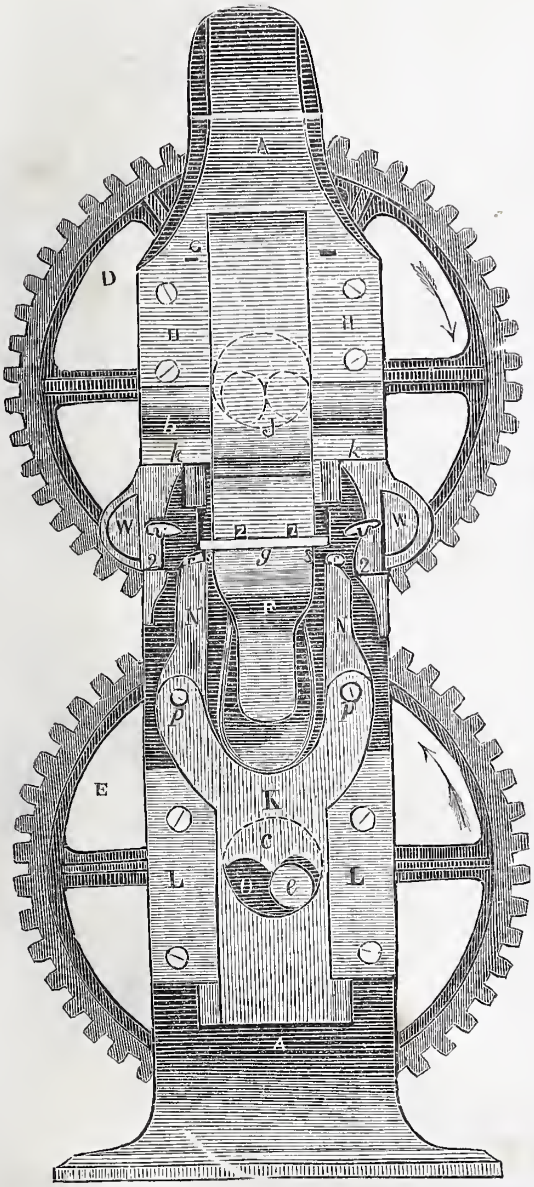
Fig. 5 is a pillow-block, which can be accurately fitted together by the machine.

This machine is fitted to plane 42 inches in length, and to a circle 36 inches in diameter.

## BARLOW'S IMPROVEMENTS IN RAILWAY CHAIR MANUFACTURE.

THIS invention consists in improved machinery for the manufacture of railway chairs. The patent is dated January 14, and enrolled July 14, 1851, in the name of Charles Barlow, Esq., of Chancery Lane, London. The chairs are formed from plates or flat bars of wrought-iron, by one operation of this machine, according to the following process:—First, a piece of plate, of the required shape and size, is cut off; it

Fig. 1.




is afterwards pressed between two dies, one of which is stationary, and the other attached to a vertical sliding-head, by which the edges are bevelled, and the holes of the spikes are punched; the lips are then cut and formed by two cutters, secured to swinging arms, attached to another vertical sliding-head; and, finally, the chair is thrown out in a finished state, all by the same movement of the machinery, each revolution of the driving-shafts forming a chair.

The operation of this useful machine will be easily understood by referring to the engravings, which we shall describe in detail.

Fig. 1 is a front elevation of the machine; fig. 2 is a vertical section, taken from back to front through the centre; fig. 3 is a vertical section of the working parts detached, taken through the centre of the dies, in a plane parallel to the front; fig. 4 is a side elevation of the working parts, the guides being removed, and part of the frame, to which the parts are attached, being shown in section; fig. 5 is a plan or top view of the lower die and cutters, which cut and bend the jaws of the chair; fig. 6 is a detached view, in perspective, representing the upper die inverted, and slightly opened; and fig. 7 is a perspective view of the chair. Similar letters of reference indicate the corresponding parts in each of the figures.

The frame of the machine is represented by the letters A A; it is of cast-iron, in one piece, and consists of a bed-plate and two vertical posts, united by an arch at the top. B and C are the shafts of the toothed wheels, D E, and are mounted in suitable bearings, *b b* and *c c*, in the frame. The wheels, D E, are of equal size, and gear into each other. The shafts, B and C, are respectively provided with the eccentric studs, *d*, *e*, which are also of equal size, and are placed at equal distances from the centres of their respective shafts. F (figs. 1, 3, 4) is a small table or shelf projecting from the front of the frame, and *f* (figs. 3, 5) is the stationary flat steel die, which is firmly secured by screw-bolts to the table, F. The die, *f*, is quadrangular like the chair, *x*, and has recesses, 1, 1, (fig. 5,) on each side; it is farther provided with four small square punches, *o*, *o*, *o*, *o*, standing out upon its face.

*g* (figs 1, 2, 4) is a steel cutter for cutting off the required size from the plate. It is secured in the table, F, in front of the die, *f*, and its cutting edge, by which it divides the plate, projects above the face of the die.

G, is the upper cast-iron head, sliding freely on the vertical guides, H, H, secured to the front of the frame. It is provided with a curved slot, (fig. 2,) in which the eccentric stud, *d*, fits, so as to raise and depress the sliding-head by each revolution of the shaft, B. J, is an arm jointed to the upper part of the head, G, in front of it, by the hinge, *h*. In fig. 1, it entirely covers G; in figs. 2 and 3, the sections of both arms are shown. The arm, J, is provided with a projecting piece, *i*, on its inner side, (fig. 2,) which, when the arm is close, fits accurately in a recess in front of the arm, G. On the outside of the arm, J, is a boss, armed with two pins or studs, *k*, *k*, which move in inclined slots or grooves in cheeks, *l*, *l*, projecting from the front of the frame.

The upper die, corresponding to the lower one, *f*, is represented by the letters, *m*, *n*, and is formed of two pieces of steel-plate, attached respectively to the arms, G and J. The reason of dividing it will be explained afterwards. The larger division, *m*, is secured to the under side of the vertical sliding head, G, and the smaller one, *n*, is secured, in like manner, to the lower end of the arm, J. The die, *m*, *n*, viewed as one piece, corresponds in size and form to *f*; it has two similar recesses, and is provided with four square holes, in which the punches, *o*, *o*, *o*, *o*, of the die, *f*, fit. It is farther provided at its corners with projecting rims or catches, of nearly the thickness of the plate, to prevent any lateral motion of the plate when being compressed between the dies. The interior sides of the projections are bevelled, by which a bevel edge is communicated to the plate. The recesses are in the *m* division of the die, and at these parts the edges of the die project over the bottom of the head, G. K, is another cast-iron head, sliding in the vertical guides, L, L, and furnished with a curved slot, O, like the head, G. To its upper end are attached two arms, M, M; and again, to the upper ends of these, two other arms, N, N, are jointed by the hinges, *p*, *p*, which admit of a lateral movement. The moveable arms, N, N, are fitted at their upper extremities with flat steel plates, *r*, *r*, (figs. 1, 3,) and these again are furnished with projecting parts, *s*, *s*, which fit the recesses, 1, 1, in the lower die, and form with it shears for cutting

and bending the lips of the chair. The front edges of the projections, *s, s*, are bevelled or inclined, as shown in fig. 1, and the back edges are also bevelled off to nearly a point, but the side edges are sharp, for the purpose of cutting through the plate. Secured to the top of the head, K, is a curved spring, as shown in figs. 1, 3, the tendency of which is to keep the arms, N, N, distended. *v, v*, are flat steel plates, rounded at their back ends to fit corresponding recesses in the cheeks, *w, w*, which project from the frame; their front edges are bevelled or inclined, corresponding to the bevelled projections on the back edges of the plates, *r, r*. The chair, *x*, is shown in its finished state in fig. 7; it is shown in section, in lines, in figs. 2 and 3, and in the act of leaving the machine in fig. 4.

We shall now describe the operation of the machine:—The toothed wheels, D and E, being set in motion by a pinion, cause the shafts, B and E, to revolve in opposite directions, as indicated by the arrows in fig. 1. The studs, D and E, attached eccentrically to the shafts, and working in the slots, I and O, communicate a vertical motion to the heads, G and K,

Fig. 2.

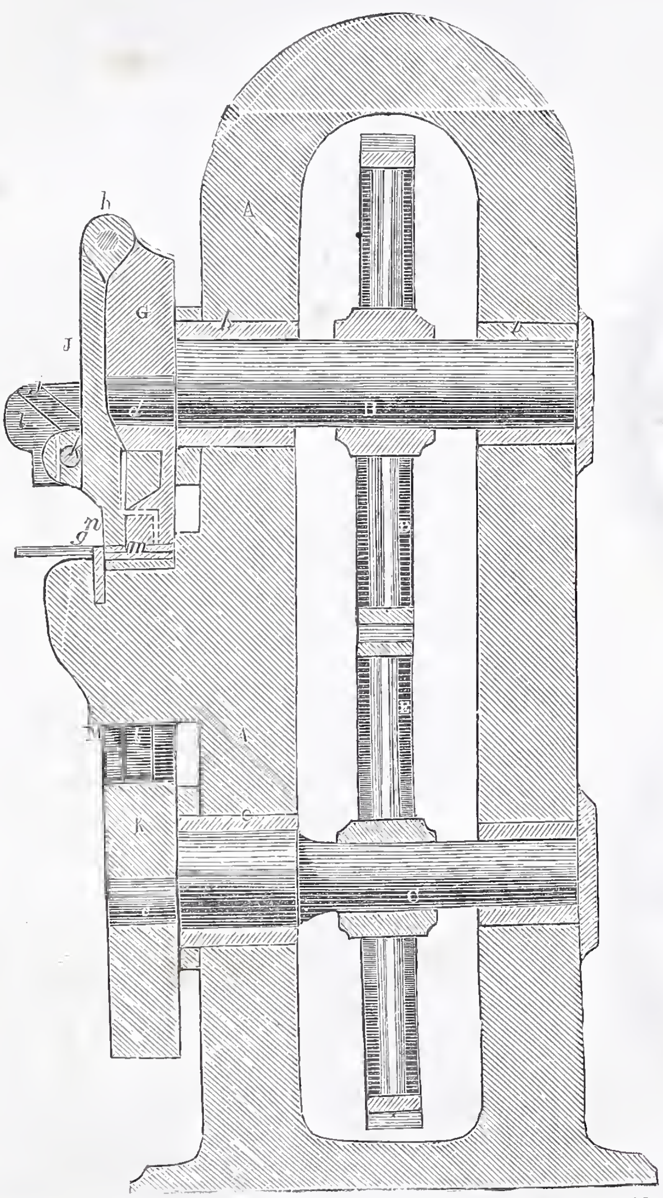
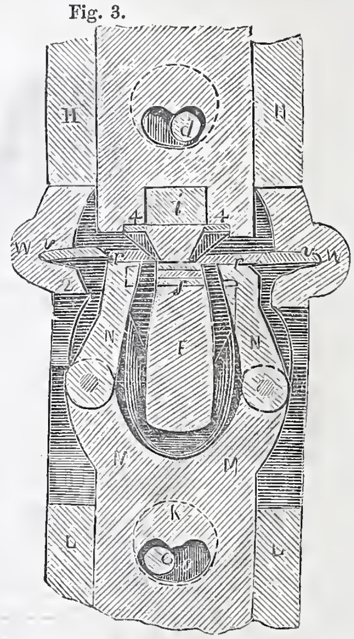


Fig. 3.



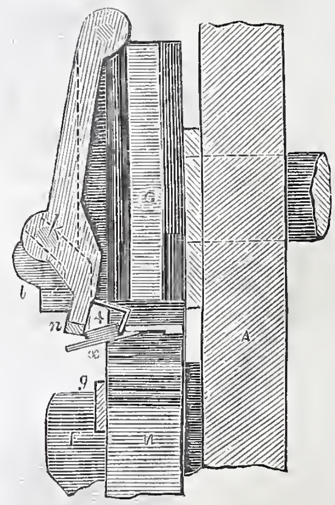
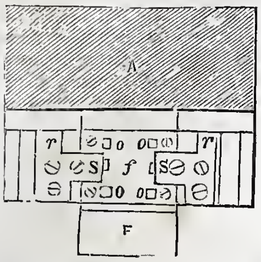


Fig. 4.

causing them to slide up and down at regular intervals. In fig. 1, the stud, *e*, is shown performing its revolution in the slot, O. The plate or bar of iron is previously made of the required width and thickness of the chair, and being well heated, is thrust into the front of the machine, over the table, F, as shown in fig. 2. The bar is placed so as to rest on the cutter, *g*, and is thrust up till arrested by the stop. When the head, G, descends, the die, *m, n*, closes upon the plate, and the outer edge of the division, attached to the under side of the arm, J, being in a line immediately within the edge of the stationary cutter, *g*, operates in the manner of shears, by cutting the required length off the plate. At the same time as the upper die, *m, n*, closes on the lower and stationary die, *f*, the punches, *o, o, o, o*, penetrate the plate, forcing the pieces cut out through the corresponding holes in the upper die, from which they are discharged through apertures, *z, z*, two in front and two at the back of the upper die. The lower part of the slot, I, being at that time con-

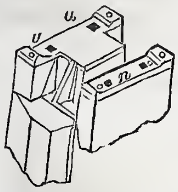
centric with the shaft, B, as shown by the state of the machine in fig. 2, the dies remain closed for some time, the eccentric stud, *d*, keeping down the upper die. In the meantime, and while the dies remain closed, the stud, *e*, is working upwards in the slot, O, and raises the sliding-head, K; the arms, N, N, being thrown apart by the curved spring already noticed, cause the inclined edges on the backs of the plates, *r*, *r*, to bear against the inner parts, 2, 2, of the cheeks, *w*, *w*, as shown in fig. 1, and the plates, *r r*, still ascending, the sharp edges at the sides of the projecting parts, *s*, *s*, pass the edges of the recesses, 1, 1, in the dies, with which they form shears, and cut two notches in each side of the plate, as shown in fig. 7. The parts, 3, 3, between the notches, have yet to be shaped to form the lips of the chair. For this purpose the head, K, continues ascending till the back edges of the cutters, *r*, *r*, having passed the part, 2, 2, of the cheeks, by which they were compressed into the recesses of the dies, fall back into recesses under the plates, *v*, *v*, and the bevelled edges of these plates causing the front edges of the cutters, *r*, *r*, to move towards each other as they ascend, the parts of the plate, marked 3, 3, are bent round the recessed parts of the upper die, *m*, so as to assume the form exhibited in fig. 7.

Fig. 5.



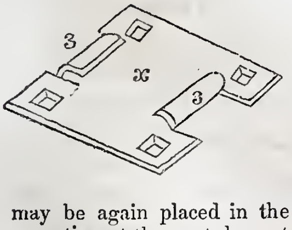

The chair is now completely formed, and only remains to be thrown out of the machine to give place to another portion of the plate. The mechanism by which this is effected is also very ingenious, and involves an explanation of the action of the upper die, and why it is formed in two parts.

Fig. 6.



It is obvious, that if the die were in one piece the chair could not be removed, on the ascent of the head, G, in consequence of the lips being bent upward and backward round the recessed parts of the die. But as soon as the lips are formed, the cutters, *r*, *r*, have passed the plates, *v*, *v*, and having now more lateral room, are immediately thrown wider apart by the distending spring. In the meantime, the stud, *d*, on the upper shaft, B, has begun to cause the head, G, to ascend. The latter, by its upward motion, raises the chair out of the punches in the lower die, *f*, and, as it rises higher, the arm, J, is thrown forward, so as to open the die by means of the studs, *k*, *k*, which run up the inclined grooves, *j*, *j*, in the cheeks, *l*, *l*, (fig. 2.) By this movement, two small steel fingers or clearers, 4, 4, (fig. 4,) attached to the inside of the arm, J, which, when the die was shut, were lodged in recesses in the back part of the head, G, are drawn forward, dragging the chair, in a line parallel to its lips, from the part, *m*, of the upper die, as shown in fig. 4, where one of the lips of the chair is seen pushed forward by the steel clearer. The chair then falls out, and the bar may be again placed in the machine, to repeat the same operation at the next descent of the upper die.

Fig. 7.




By referring to figs. 1 and 3, it will be seen that the plates, *v*, *v*, are allowed a little play in the recesses in which they are lodged. This is for the purpose of allowing the cutters to be thrown back suddenly, after passing them either upward or downward, so as to keep them no longer than necessary in contact with the heated iron-plate. The dies and plates are described by the patentee as being made of steel-plate, but they may also be made of chilled iron, or, by a still simpler process, the ends of the heads and levers may be cast in the required form, and have their faces chilled. The frame may have two dies of the same construction, one on each side, the machinery of both being moved by the same shafts. The patentee claims—

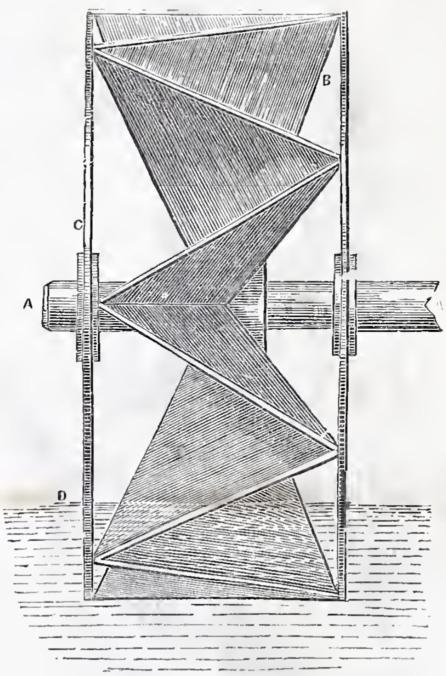
First, the upper die, *m*, *n*, constructed in the manner described, and parting or opening by a jointed arm, or by any other mechanical contrivance, for the purpose above set forth.

Secondly, the shears, consisting of the arms, N, N, having their working edges and faces, *r*, *s*, of steel or chilled iron, working in connection with the operating die, *m*, *n*, in such a manner as to cut and form the lips of the chair at one operation.

Thirdly, the combination of dies, punches, shears, benders, and clearers, arranged and operated in the manner and for the purposes herein set forth, or any other mechanical combination substantially the same.

## THE FAN PADDLE-WHEEL.

The merit of this invention—a model of which was sent to the Great Exhibition—resides in the simple exposition of a new principle of propulsion, applicable to every description of steamer, and especially so to all that cannot be adapted to the submerged screw. The inventor and patentee is Mr. Lee Stevens, the original proprietor and editor of the *Shipping Gazette*. The principle will be seen at once by the annexed drawings and references. It consists of a continuous propelling surface in the form of a rotary fan—from its perfect resemblance to which it derives its name. The




paddle-blades are triangular, and radiate obliquely from the axis, being joined together at their sides from the centre of the wheel to its circumference. They thus enter, pass through, and leave the water at inclined angles, giving it a motion or impulse to the right and left alternately, but never, in any case, impinging upon it by successive sudden collisions, and thus avoiding the vibratory motion caused by the ordinary paddle. The fan-blades are supported and strengthened by brace-zones and arms, connected with the same shaft, as shown in the figure. These zones, by compressing the water, and giving compactness to the apparatus, tend likewise to equalize and improve the propulsive effect.

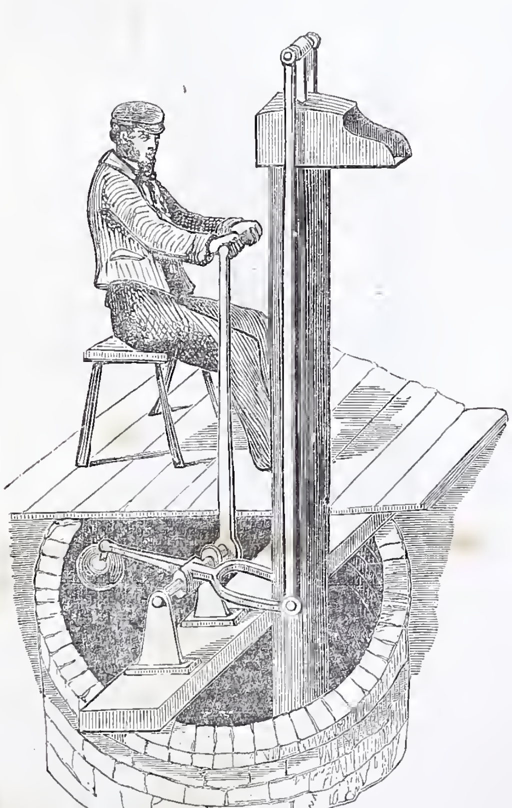
This simple, ingenious, and, apparently, most effective contrivance is expected, by many high authorities in nautical engineering, to cause a complete revolution in surface propulsion, being applicable to all surface-propelled vessels, and offering the following advantages:—

1st. Simplicity, strength, and economy of construction.
2d. Reduced disturbance of the water; no backwater.
3d. Avoidance of vibration by continuity of action.
4th. Increased speed by the saving of power consequent upon continuity of action, and upon the entrance of each segment or blade, and its exit from the water, edgewise or obliquely instead of horizontally.
5th. And decreased retardation from occasional deeper immersion.

We believe that increase of speed is anticipated from its use to the extent of from one-eighth to one-sixth upon the previous velocity, with the same motive power; so that, for example, the passage across the Atlantic may be made in a day or two less than by the fastest steamers now running. This, however, remains to be ascertained by experiment. The principle is a combination of the screw and the paddle.

## BAKER'S DOUBLE POWER BEAM-PUMP.

While an incredible amount of skill and ingenuity has been put forth in substituting self-moving machinery for manual labour, comparatively little attention seems to have been given to the very important object of rendering manual operations less laborious and irksome than they are in ordi-



nary cases. This is a department in which there is much room for improvement. Manual operations, of even the most laborious character, can never be entirely superseded by steam or water power; there must always be a large margin of work left to the effort of the human muscle and sinew, as in operations with the spade, the axe, the carrying of loads, &c. Sometimes, however, a very simple application of one or other of the mechanical powers will greatly diminish the muscular effort necessary to be put forth in such cases, and of this we have a good illustration in Baker's double power beam-pump, of which a sketch is annexed. When using the ordinary pump, the position of the arms is highly unfavourable for the lungs, and a considerable portion of the man's power is wasted in merely keeping himself in motion, the effort required bringing into play most of the muscles of the body. Our sketch exhibits a well-pump fitted on Mr. Baker's improved plan, by which it will be seen that the vertical motion is converted into a horizontal one, and the man may be seated during the operation of pumping, as in rowing. The posture in which the latter operation is performed, is known, from practice as well as theory, to constitute that in which a man may exercise the greatest power with the least fatigue to himself; and this operation of pumping on Mr. Baker's improved plan is precisely similar, calling the same muscles into play, and leaving some of the strongest of these at liberty to take their share of the work, instead of being chiefly employed, as in the ordinary operation of pumping, in supporting the weight of the body. The analogy between this improved method and that of rowing renders it peculiarly applicable on board ship, where sailors will naturally prefer the position and the method of putting forth their strength to which they are most accustomed. Jack has usually a strong aversion to pumping, and seems to regard the operation as little better than the labour of a crank machine fitted up for a punishment. Mr. Baker's plan must go far to remove his objections, by not only giving him a posture to which he is more accustomed, but actually rendering the operation less laborious. While generally applicable, therefore, to every species of hand-pump, this improved method seems to be peculiarly adapted for ships; and there can be no difficulty in applying the principle either by land or sea. The mode of its operation is sufficiently obvious from the sketch.

## ASTRONOMY

### CHAPTER II.

#### HISTORY AND PROGRESS OF ASTRONOMICAL DISCOVERY CONTINUED.

When the mighty empire of Alexander the Great came to be divided at his death amongst his generals, Egypt, fortunately for the sciences, fell to the lot of Ptolemy Soter. For the next three generations, the Egyptian monarchs, the Ptolemies, were the most liberal and munificent patrons of literature and art; the learning of Greece, and of other parts of the world, was attracted to the capital of Egypt; a magnificent library was founded; and Alexandria, for several ages, shone like a meteor in the sky, illuminating for a time the darkness in which the world of letters was overwhelmed.

Amid the cultivation of the other sciences, astronomy was not neglected; every book and every instrument which could facilitate its study were procured, and a succession of astronomers arose, who, by new observations, by collecting and correcting those of their predecessors in the science, by generalising their facts and drawing sound conclusions, did more to raise astronomy to the rank of a science in one century than had ever been done before. Hitherto, no idea had been formed of the vast difference in the distances from the earth of the planets and the fixed stars; all the heavenly bodies were crowded round the globe at distances of which they could form no conception; now, however, the science began to be founded on a firmer basis. The paths of the planets were followed with the greatest care, and their distances roughly ascertained, while the fixed stars retreated to an immeasurable distance beyond: the irregularities of the

# TELESCOPIC APPEARANCE OF THE MOON

J. Scott.

he appearance of the Moon as seen through Lord Rosse's great telescope is thus described by Dr Scoresby "It appeared like a Globe of Molten Silver, nd every object of the extent of a hundred yards was quite visible. Edifices therefore of the size of York Minster might be easily perceived, if they had xisted. But there was no appearance of any-thing of that nature; neither was there any indication of the existence of water or of an atmosphere. here was a vast number of extinct volcanoes, several miles in breadth through one of them there was a line in continuance of one about 150 miles in ength, which ran in a straight direction like a railway. The general appearance however was like one vast ruin of nature."

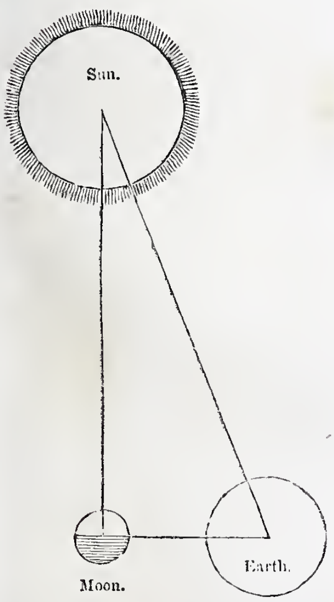
LUNAR CRATER

sun and moon became better known and understood: astronomical instruments and the science of mathematics were brought to the aid of a series of connected observations; and thus was laid the foundation of a science that was destined to unravel the mysteries of the heavens, and to unfold those sublime views of the majestic works of the Almighty Creator, which inspire us with wonder, reverence, and awe!

The first astronomers of note in the Alexandrian school were Aristillus and Timocharis; their observations were chiefly confined to the planets, and to the determination of the position of the stars with regard to the equinoxes and the equator. They flourished about three hundred years before the Christian era.

About one hundred and twenty years later, Aristarchus of Samos was a celebrated astronomer of this school. It is said that he adopted the theory ascribed to Pythagoras in regard to the earth's motion round the sun; and from observing that the stars had the same fixed position when viewed from opposite points of the earth's orbit, he concluded that their distance, compared to that of the sun, was immense. A small work of Aristarchus, "On the Magnitudes and Distances of the Sun and Moon," has descended to us; but in it no mention is made of his hypothesis of the earth's motion. It gives us, however, his celebrated method of measuring the relative distances of the sun and moon, as follows. It can easily be seen that when the moon has exactly half her disc illuminated by the sun, a line joining the sun and moon will be perpendicular, or at right angles, to a line joining the earth and moon, as represented in fig. 3. Then by measuring the angle at E (which can be done, the sun and moon being both visible at the same time above the horizon), and knowing the right angle at M, the proportion of the sides can be found by a trigonometrical problem. The principle was perfectly correct; but the means did not exist then, nor for many a long century after the days of Aristarchus, of taking the advantage of his discovery.

Fig. 3.




The next great astronomer of the Alexandrian school was Eratosthenes, a Grecian philosopher, who was born at Cyrene, B.C. 276. His fame reached the ears of Ptolemy Euergetes, who invited him to Alexandria, and appointed him royal librarian. He was an excellent mathematician, geographer, and astronomer: he found the obliquity of the ecliptic, or the distance between the sun's place in the heavens at the solstice and at the equinox, to be 23° 51′ 20″, which is nearly the same as that found by his successors, Hipparchus and Ptolemæus (vide fig. 4). He is chiefly remarkable for his ingenious method of attempting to measure the circumference of the earth. He fixed upon two places situated in the same meridian, at some distance from each other: Syene, now called Assouan, in Upper Egypt, where the sun was vertical at noon at the summer solstice, and Alexandria, where at the same moment the sun was below the zenith, by $\frac{1}{50}$ of the circumference of a circle, or 7° 12′. As the arc of the circle, therefore, is to the distance between the two places, so would a whole circle, or 360°, be to the circumference of the earth, which is thus found by multiplying the distance between the two places by 50. But although the principle was quite correct, his data were not sufficiently exact, and his instruments for measuring the distances were by no means accurate; so that it is far from surprising that his calculation was wide of the truth.

Conon of Samos, Archimedes the great geometrician, and Apollonius of Pergæa, were all names of celebrity in the science; the last is said to have introduced the *epicycle* and *deferent circle* to explain the stations and retrogradations of the planets; but by far the greatest ornament of that age was HIPPARCHUS, who is justly celebrated as the Newton of antiquity, being the first on record who was really a systematic observer, and who drew up, for the benefit of his followers in the science, a digested body of astronomical observations. He flourished about one hundred and forty years before Christ: he began his labours in astronomy by taking none of the observations of his predecessors as correct, but, by putting every one of them to the test, instituting a series of his own, and separating truth from error. Having verified the obliquity of the ecliptic, as settled by Eratosthenes, and fixed the latitude of Alexandria, he proceeded to ascertain the exact length of the year, which he did to within six minutes of the truth. In the course of these investigations, he discovered that the interval between the vernal and autumnal equinox was nine days longer than the interval between the autumnal and vernal, and that the period between the vernal equinox and summer solstice was two days longer than that between the solstice and the autumnal equinox. Hipparchus held the opinion entertained by every astronomer down to the days of the immortal Kepler, that *the motions of all the heavenly bodies were circular and uniform;* and to reconcile the discrepancy between the above periods, he supposed that the earth was placed at some distance from the centre of the sun's circular orbit, which accounted for the apparent variation in his velocity. He made numerous observations and discoveries in connection with the motions of the sun and moon, which will be better understood when we come to treat of these bodies. He is deservedly celebrated as the first astronomer who attempted to form a catalogue of the fixed stars. The appearance of a new star in his time is said to have incited him to this magnificent and herculean task; and, in order that future observers might know if any changes should occur in the heavens, he fixed the latitude and longitude of 1022 stars. He was the first who thought of mapping out the heavens on a plane surface, being thus the inventor of the planisphere. This method of representing the positions of the stars he transferred to geography, so that he was the first to determine the situation of countries, towns, &c., by lines of latitude and longitude. He also laid the foundation of plane and spherical trigonometry. One of his discoveries deserves to be mentioned somewhat in detail, as it gives evidence of an accuracy and acuteness of observation perfectly surprising for the age in which he lived. The sun's annual path backwards among the fixed stars, called the line of the ecliptic, had been hitherto regarded as unchangeable, and the two points which he occupied in the heavens during the equinoxes as completely fixed; so that, if a star should be selected to mark the sun's position while crossing the equator, the equinoctial period could be easily known or foretold by ascertaining the sun's distance from this star. But Hipparchus discovered that the sun's path among the stars was *not* unchangeable, that the equinoctial points were *not* immoveable, and that the star which was chosen by Aristillus and Timocharis, one hundred and seventy years before, to announce the equinoctial period, failed to do so now. He therefore arrived at the just conclusion, that the sun's position in the heavens at these periods is not fixed, but moving westwards at a very slow rate; and this phenomenon is called the *precession of the equinoxes.* The principal part of the works of this great astronomer perished at the destruction of the Alexandrian library. His catalogue of the stars is preserved by Ptolemæus, and one or two small works attributed to him have escaped the ravages of time, and are still extant.

After Hipparchus, no astronomer of note appears on the

scene till we arrive at Ptolemæus, who flourished about the middle of the second century of the Christian era, and who developed the earliest complete system of the science which has reached our time. Ptolemy had the good fortune to live at a period when the field of astronomical research was unoccupied, and when he could avail himself not only of the observations and discoveries of the ancients, but of the vast store of precious materials left by his illustrious predecessor Hipparchus. But, independently of these advantages, he was possessed of an intellect of a very superior order. He was an excellent practical astronomer, the best geographer of antiquity, a chronologist, musician, and optician. After collecting and digesting the discoveries and theories of the ancients, and particularly those of Hipparchus, and adding the several discoveries and extensive observations of his own, he drew up a complete system of the universe, which was called many years afterwards, by the Arabian translator, *The Almagest, or Great Composition,*—a work which continued to be the universal text-book in astronomy, as the works of Galen were in physic, and those of Aristotle in philosophy, for more than fourteen hundred years. His system is called the Ptolemaic. In the centre of it is placed the earth, around which the sun, moon, planets, and starry heavens perform their daily revolutions from east to west, with perfectly circular and uniform motions. The planets are placed in their proper order as regards their distances from the earth; the fundamental error of Ptolemy consisting in his placing the earth instead of the sun in the centre of his system. This astronomical theory accounted for the apparent diurnal revolution of the heavenly bodies; but it failed to account for the irregular motions of the planets, which appear to an observer to move at one time faster than the fixed stars, then to stop, next to retrograde, to stop again, and then to move on as before, describing loops, as it were (vide fig. 5). To account for these irregularities, Ptolemy had recourse to a combination of circles. He supposed that the planets not only performed their daily revolutions round large circles, near the centre of which the earth was fixed, but that they also slowly moved round small circles, the centres of which were carried round the large circles. To the large circles he gave the name of *deferents,* to the small, *epicycles* (vide fig. 6). It will be seen from the figure, that a planet would appear to a spectator on the earth to move forward, to stop, and to retrograde in moving slowly round the epicycle, the centre of which was supposed to be carried round the *deferent* circle in the daily revolution of the heavenly bodies. The Almagest of Ptolemy contains a method of calculating eclipses; but whether original or borrowed from Hipparchus, we are not informed. He adopted the theory of this astronomer to account for the variations in the velocity of the sun, moon, and planets, by placing the earth at some distance from the centre of their orbits: this was called their *eccentricity.*

The Ptolemaic system of astronomy, however erroneous, was so ingeniously constructed that it accounted for all the phenomena; and, with the few and rude instruments then known, the number of their discoveries, and the accuracy of their observations, show with what ardour and perseverance these early astronomers prosecuted their researches, and with what intellectual power and ingenuity they could grapple with the difficulties that came in their way.

At the death of Ptolemy, the light of science, which shone with varied brightness on the school of Alexandria for three hundred years, began to languish; and though, for several centuries afterwards, a faint glimmering appeared, it received no new accession to give it strength, and it gradually became extinct. By the fall of the Roman empire in the west, and the ravages of Mohammed and his successors in the east, the arts and sciences were buried in oblivion, and all memorials of their previous existence seemed in danger of being obliterated for ever. At length, however, the Arabian princes grew tired of war, a desire to cultivate the arts of peace began to return, and Bagdad became the seat of the sciences. In the beginning of the ninth century, Almamon invited to his capital the most distinguished philosophers and learned men of the day. He acquired possession of the Greek manuscripts that were deposited at Constantinople, and the *Almagest* of Ptolemy being among the number, he caused an Arabic translation to be made, thus rescuing the science of astronomy from oblivion, and giving a new impulse to its cultivation and study. By the exertions and encouragement of Almamon, a succession of astronomers appeared, who not only corrected and promulgated a knowledge of the observations of their predecessors, but made considerable additions of their own. The greatest name among the Arabian astronomers was Albategnius, governor of Syria: his corrections and additions were of considerable value to the science. With his life, however, terminated what may be called the astronomy of the Arabians; and although it rather advanced than retrograded in their hands, the advantage gained in this respect was slight compared to the far superior benefit they conferred on it and on the world, by introducing a knowledge of the science into every country which they ruled; so that when the Arabian yoke was thrown off, this knowledge remained, took root in its new soil, grew up and bore abundant fruit, or withered away, according to the capabilities of the ground in which it was sown, and the intelligence and perseverance of the husbandmen. Astronomy was cultivated in Persia during the eleventh, twelfth, thirteenth, fourteenth, and fifteenth centuries; and Ulugh-Beigh, a Tartar prince, and grandson of Tamarlane the Great, made a distinguished figure in the science: he made a new catalogue of the fixed stars, and framed astronomical tables nearly as accurate as those of Tycho Brahé. But it was in Europe that the seed sown by the Arabs found congenial soil. Alphonso X., king of Castile, was the first European prince who gave an impulse to the study and advancement of astronomy. Towards the middle of the thirteenth century he founded a college at Toledo, at a great expense, and assembled all the learned Arabians in Spain, by whom the celebrated Alphonsine tables were drawn up and published in 1252.

From Spain, a knowledge of the principles of astronomy, as then taught, soon spread over Europe: men of the highest intellect and genius directed their attention to the study of the science. About the middle of this century (thirteenth), Roger Bacon, a learned friar and philosopher, flourished in England: he clearly anticipated the discovery of the telescope, the camera obscura, and gunpowder; and he not only detected the error of the calendar, but actually suggested the reformation afterwards made in it by Pope Gregory XIII.

Nicholas de Cusa, an obscure priest of the Church of Rome, appeared in France, and discovered several errors in the Alphonsine tables. Hitherto the researches of the most learned men failed to bring to light any other system of astronomy but that of Hipparchus and Ptolemy. All the nations of the world held, as incontrovertible maxims, that the earth on which we live is motionless and the centre of the universe, and that the motions of the heavenly bodies are circular and uniform. By the system of Ptolemy, all observed phenomena were apparently so well accounted for, that the boldest innovator never thought of calling in question these primary ideas. Even the doctrine of the earth's motion which is ascribed to Pythagoras, upon questionable authority, seems to have arisen solely from that spirit of holding opposite opinions which distinguished the ancient schools of philosophy. Nicholas de Cusa, then, may be said to be the first on record who in all sincerity departed from the received opinions, and advanced the startling proposition, that "*the earth moves, the sun is at rest.*" He answered the objections to this doctrine which arise from its being contrary to the evidence of the senses, by contending that this illusory impression occurs from the same cause which makes a person, sailing in a ship, fancy the objects on land in motion, and the ship at rest. These opinions he inscribed to his former preceptor, Cardinal Cesarini of Rome; and on account of his learning and talents he was rewarded with the archdeaconry of Liego. He attended the celebrated Council of Basil in 1431, and presented to that assembly a treatise on the errors of the calendar, with a proposal for its reformation. Pope Nicholas V. subsequently raised him to the dignity of a Cardinal, and gave him the bishopric of Brixen

in the Tyrol. The publication of his works was one of the first tasks of the Italian press, under the sanction of the celebrated French Cardinal Amboise.

John Muller, surnamed Regiomontanus, flourished in Germany at this period; he was the pupil of Purbach, also a famous astronomer, of Vienna. Regiomontanus acquired such a reputation from his numerous translations of the Greek authors, his treatises on trigonometry, mathematics, and astronomy, that he was raised to the Archbishopric of Ratisbon; and under promise of the highest rewards he was induced, by Pope Sextus IV., to go to Rome and reform the calendar. He did not live, however, to accomplish the task, for shortly after his arrival he was seized with the *plague* of which he died in 1476.

Bernard Walther, of Nuremberg, was the friend and disciple of Regiomontanus. He continued the researches and observations of his master, and is regarded as the first discoverer of the regular effect of atmospheric refraction. John Werner, a priest at Nuremberg, was the next who acquired a high reputation in the science. Having become master of astronomy at Rome, he returned home and devoted himself to the observation and study of the heavenly bodies. He described the orbit of the comet of April, 1500: he translated the Geography of Ptolemy; and in an appendix which he added, he explained the method, which is used at the present day, for finding the longitude at sea by the distance of a fixed star from the moon. He also made out the precession of the equinoxes to be 1° 10′ in 100 years.

At this period also flourished the celebrated Leonardo da Vinci, who is chiefly known as an illustrious Italian painter, but whose universal genius is now known to have completely mastered the sciences of sculpture, architecture, engineering, botany, anatomy, mathematics, and astronomy. Indeed his greatest literary distinction is derived from short fragments of his writings, which were published at the end of last century. "The discoveries," says Mr. Hallam, "which made Galileo, and Kepler, and Maestlin, and Maurolicus, and Castelli, and other names illustrious, the system of Copernicus, the very theories of recent geologists, are anticipated by Da Vinci, within the compass of a few pages, not perhaps in the most precise language, or on the most conclusive reasoning, but so as to strike us with something like the awe of preternatural knowledge." * He took up the idea of the mobility of the earth propounded by Cardinal Cusa with avidity and ardour: he connects, indeed, in 1510, his theory of the fall of bodies with the earth's motion as a thing generally received, proving more than Mr. Whewell's assertion, "that the Heliocentric doctrine, and the truths of mechanics, were fermenting in the minds of intelligent men some time before they were publicly asserted."†

Already was the immortal Copernicus exciting the wonder and applause of the admiring thousands who crowded to hear his lectures as professor of mathematics at Rome. Born at Thorn, in Prussia, in 1473, and having received the rudiments of his education in his native city, and obtained the degree of Doctor of Medicine at the University of Cracow, he repaired to Italy to study the science of astronomy, which was more congenial to his inclination, under Domenico Maria of Ferrara, who was then mathematical professor at Bologna; "and there is reason to believe," says Sir D. Brewster, "that Maria's hypothesis of the variability of the axis of the globe, suggested to Copernicus the idea of explaining the celestial phenomena by the motion of the earth."‡ From Bologna he went by invitation to Rome, about the year 1500, to fill the chair of mathematics there. In Rome he adopted the opinion that the sun was fixed in the centre of the universe, while the earth and all the other planets revolved around him; that as the apparent motion of an external object may arise from the motion of the spectator, so the apparent annual motion of the sun arose from the motion of the earth around him in a year, and the apparent daily revolution of all the heavenly bodies was solely owing to the diurnal rotation of the earth on its own axis. The apparent irregular motions of the planets, their stations and retrogradations, were thus easily explained, from their being viewed by an observer at so many different points of the earth's orbit round the sun.

Having been struck with the complexity of the Ptolemaic system, and with the utter improbability of the vast sphere of the stars revolving round the earth every twenty-four hours; having seen it reported that Pythagoras and several of the ancient philosophers countenanced the idea of the earth's motion; being in a more particular manner influenced, as he himself informs us, by the system of Martianus Capella, a Roman author of the fifth century, who placed the sun between Mars and the moon, and made Mercury and Venus revolve round him as their proper centre; and being also, no doubt, very much swayed by the opinion on this subject that had been generally prevalent among the learned men of Italy,‖ since the time of Cardinal Cusa, nearly a century before, Copernicus matured the astronomical system which has immortalised his name, while professor of mathematics at Rome. There he also wrote the greater part of his celebrated work, "*De Revolutionibus Orbium Celestium*," and not, as is commonly reported, after thirty years of observation and research in his secluded retreat as priest at Frauenberg. "His discovery of his system," says Professor Whewell, "must have occurred before 1507; for in 1543 he informs Pope Paul III., in his dedication, that he had kept his book by him for four times the nine years recommended by Horace."§

To gratify his desire for seclusion, and to enable him to establish the truth of his theory by actual observation, Copernicus returned to his native country, probably about 1510, and having taken holy orders at Rome, he was presented by his uncle, the Bishop of Ermeland, with a canonry in the chapter of Frauenberg. Here he exclusively devoted himself, during the rest of his days, to his ecclesiastical duties, to gratuitous medical practice among the poor, and to the pursuit of his favourite science—astronomy. He made a series of observations on the planets, and, by the aid of instruments which he invented for the purpose, he constructed tables of their motions on a far more correct scale than had ever been done before. In 1516, the Lateran Council was employed at Rome in correcting the calendar. Its president, the Bishop of Fossombrona, and its secretary, the Dean of Frauenberg, wrote urgent letters to Copernicus, soliciting his aid in their important task; but his mind had been too much occupied with other investigations, to allow him to direct his attention to this subject. He, however, afterwards did so, and rendered important assistance.

In 1530, his great work was still unpublished. Imbued as he was with a strong conviction of the truth of his theory, the instruments he possessed, and the state in which the science existed at that age, rendered it impossible for Copernicus to offer his doctrine to the world as anything but a pure hypothesis. True, it was simpler than the Ptolemaic; but the Ptolemaic accounted for the phenomena, and his did no more; while it was directly opposed to the evidence of the senses, which the Ptolemaic was not. Its truth was at that time incapable of demonstration, and subsequent discovery might prove it to be either true or false: as a hypothesis, therefore, he did offer it, as is seen from the preface, title, and dedication of his book. By the theory of Copernicus, the stability of the earth in the centre of the system, as supposed by Ptolemy, was transferred to the sun; but the priest-astronomer still clung to the ancient doctrine of the uniform and circular motions of the heavenly bodies; and, to account for the observed variation in their velocities at different parts of their orbits, he was driven to adopt the *eccentric* and *epicycle* of the Ptolemaic system.

But other and greater difficulties stood in the way of the new theory of Copernicus. If the earth had a circular orbit

* History of the Literature of Europe.
† History of the Inductive Sciences.
‡ Edin. Encycloped., Art. Copernicus.

‖ Vide Tiraboschi; Thomas Cornelio, Progym. de Universitate; Barbieri, Notizie Istoriche, &c.
§ History of Inductive Sciences, Vol. I. page 377.

200,000,000 miles in diameter, and if its axis had the same inclination to the plane of its orbit in going round this vast circumference, it followed that this axis ought to describe a curve around the north pole of the heavens; or, in other words, the north pole star would not be seen quite in the same position by an observer at opposite points of the earth's orbit. The most delicate instruments, however, failed to detect the slightest curve: the north pole star remained immoveable during the entire revolution of the earth around the sun. The answer of Copernicus to this objection would now be perfectly satisfactory—that the distance of the fixed stars is so immense, that the diameter of the earth's orbit is reduced to a mere point; but at that time the telescope had not been invented; the fixed stars appear to the naked eye more than one hundred and sixty times their real size, and consequently that number of times nearer the earth than they really are. This answer, therefore, was unsatisfactory, and the assertion seemed a vague conjecture. It was also urged, in opposition to his theory of the earth's diurnal motion, that bodies in falling from a height would fall a little to the westward of the perpendicular line, as during their descent the globe, moving at such velocity, would have left them some hundred feet behind. Such, however, was not found by experiment to be the case, but that all bodies fall proportionally. So deeply rooted in the human mind is the idea of the sun's motion and the immobility of the earth, that in every nation, at the present day, it is closely interwoven in the language not only of the peasant, but of the poet and the philosopher; and, with positive proofs to the contrary, it is the sun's motion—his rising and setting—that is talked of, and not the revolution of the earth.

Was it any wonder, then, that Copernicus, who advocated his theory from considerations as purely imaginary as those against which he contended—who was perfectly aware that he had nothing but presumptive evidence to advance in support of it—resting its truth almost solely on its diminished complexity—and who, moreover, could not help seeing the force of the scriptural objections which were urged against it,—was it any wonder that he shrunk from brooking the ridicule of the public, that his timidity quailed before the vulgar prejudice, and that he hesitated, and hesitated long, before his friends could prevail upon him to publish his book, and give forth his doctrines to the world? Already had his opinions been circulated among the common people; already had he been denounced by them as an infidel, a magician, a visionary; already had he been caricatured in bitter satire on the stage at Elburg; so that it was not without reason that he announced doctrines so new and so startling with extreme diffidence and after long delay.

Accounts had reached Rome in 1534, that Copernicus was prevented from publishing his book, both from the dread of communicating a violent shock to the public mind, and from the want of the necessary means. Immediately Cardinal Scomberg, bishop of Capua, wrote in the most earnest manner, and urged him to withhold his system no longer from the world; and with a liberality which must ever redound to the honour of his name, he offered to defray the whole of the expense. The Cardinal was warmly supported in his endeavours to procure the publication of the work, and in his offer of pecuniary assistance, by Gisio, bishop of Culm; but it was not till Rheticus, the friend and pupil of the astronomer, had sounded the public mind by an anonymous account of the new theory, that at last, in 1541, a tardy consent was extorted from Copernicus, and that the work was put into the hands of Rheticus to have it printed. The printing was finished at Nuremberg in 1543, at the expense of the Bishop of Culm, the generous Cardinal Scomberg having been dead for some time. Copernicus himself did not live to read a printed copy of his work, a proof impression having been given him only a few hours before he expired, on 23d May, 1543, in the 73d year of his age. His remains were deposited near the altar in the cathedral of Frauenberg, and Cromerus, bishop of Ermeland, erected a monument to his memory thirty-eight years afterwards.

His great work, "*On the Motions of the Celestial Orbs*," he dedicated to the reigning Pope, Paul III., in the hope that he would shield him against the attacks by which he was assailed on scriptural grounds. "If, perchance," says he in his dedication, "there shall be any vain babblers who, though ignorant of all mathematical science, yet assume a right to pronounce upon it, and, on the strength of some text of scripture distorted to support their views, blame and abuse my work, I let them do so; but I also will take leave to despise their judgment as rash. * * * Mathematics are written for mathematicians, who will, I think, agree that my labours are of some use to the ecclesiastical republic, of which your holiness is the head." In the anonymous preface which is prefixed to the work, and which is generally ascribed to Andrew Osiander, a German protestant, who superintended the printing, he says, "that he only advanced his views as mere hypotheses, which fulfilled the object of submitting the orbits of the heavenly bodies more conveniently to calculation, but which need not necessarily be true, or even probable."

A host of astronomers succeeded Copernicus, such as Reinhold, Frisius, Nonius, Appian, and William IV., Landgrave of Hesse-Cassel. They enriched the science with numerous and correct observations, but their discoveries were very few; and it was not till towards the end of that century (sixteenth), that a star of the first magnitude arose in the person of Tycho Brahé.

Tycho was born of noble parents at Knudsthorp, in Denmark, in 1546. While pursuing his studies at the university of Copenhagen, his mind was directed to astronomy, much against the wishes of his friends, to the neglect of almost every other branch of science, by the coincidence between the calculated and observed times of a total eclipse of the sun, on 21st August, 1560. He spent all his pocket-money on astronomical instruments; while his tutor slept, he stole many hours from his repose to study the orbs of heaven; and, by the aid of a globe not many inches in circumference, and a pair of small compasses, he detected many errors in the Alphonsine and Prutenic tables, which he afterwards corrected. Having prosecuted his favourite science for several years at various places, and become acquainted with the most distinguished astronomers of the day, he returned home in 1571, and, by the kindness of his uncle Steno, he was afforded the means of erecting an observatory and a laboratory, being also much attached to the science of chemistry. While residing here, on the evening of November 11, 1572, he discovered a new star in the constellation Cassiopeia, larger and more brilliant than the planet Venus. It continued visible for more than a year, gradually diminishing in splendour, till in March, 1574, it finally disappeared.

Through the warm representations of William, Landgrave of Hesse, one of the best astronomers of the time, Tycho was presented, by Frederick II. of Denmark, with a grant of the island of Huena for life, as a place where he might quietly pursue his investigations, with an annual salary of 2000 dollars, and with the proceeds of a fief in Norway, and a canonry in the church. On this small and solitary island in the Baltic, Tycho planned and built his famous astronomical castle, which he called Uraniberg, or "City of the Heavens," which he continued to occupy unmolested for twenty-one years, and where he gave his whole mind te the unremitting observance of celestial phenomena during the life of Frederick, and under his son, Christian IV., till 1596. His fame spread far and wide; foreigners of distinction visited the country for the sole purpose of seeing the great astronomer; King James I. of England spent a week with him on the occasion of his visit to Denmark to marry the Princess Anne. These circumstances excited the envy and jealousy of the Danish nobles: the physicians were displeased at his administering medicines gratis to the poor: the minister of the crown, Walchendrop, contrived to poison the ear of his royal master; so that he was gradually deprived of his emoluments, and in 1597 he bade a final adieu to his native land. After visiting several places with his wife and children in search of a suitable abode, he accepted, in 1599, a pressing invitation from the Emperor Rudolph II. of Bohemia to settle at Prague, as

imperial mathematician, with a salary of 3000 ducats. But the great kindness and munificence of the Emperor, the society of Longomontanus and the illustrious Kepler, who were his pupils, and the presence of his family around him, failed to soothe the troubled spirit of the exiled astronomer. He longed to return to his native country, the remembrance of his wrongs preying upon his mind, and in all probability accelerating his death, which occurred on 24th October, 1601.

To the ingratitude and inhospitallty of his country, which must ever redound to the disgrace of the parties concerned; and to the fortuitous circumstance of Tycho's spending the last of his days at Prague, are we indebted for some of the most splendid discoveries that were ever achieved in astronomical science. Here he met the immortal Kepler, whose fancy had hitherto run wild in the mazes of unsupported theory, but who, by the fatherly advice and aid of Tycho, threw idle speculation aside, and applied his brilliant genius to sound philosophical deduction from observed phenomena.

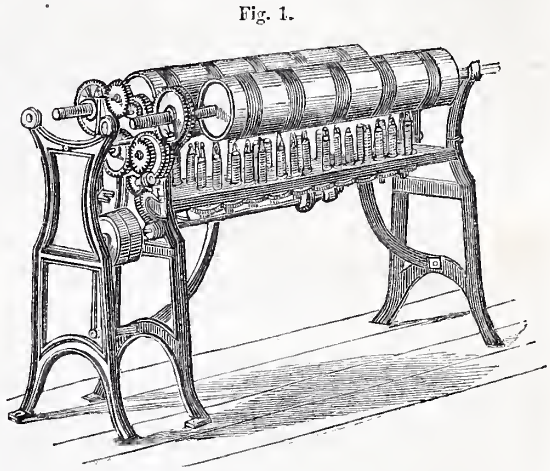
Tycho Brahé was imbued with the feudal spirit and undisciplined mind of the Danish noble: in astronomy, he was one of the most accurate observers that ever appeared; but the mental culture which he had undergone, unfitted him for the higher efforts of inductive philosophy, and when he attempted to theorize on his observations and discoveries, he often lapsed into error. It is rather remarkable that, although a protestant, and quite unfettered by the authority of the Church of Rome, he rejected the Copernican theory of the earth's motion, not only because he showed it to be a problem incapable of proof, but chiefly on scriptural grounds, on which he converted his friend Rothman to his own way of thinking. His system of astronomy, which is called the Tychonic, was intermediate between that of Ptolemy and Copernicus. He held that the earth was stationary in the centre of the universe, that all the planets and comets revolved round the sun in various periods, and that the sun and all the stars were carried round the earth every twenty-four hours. This system, though now looked upon as absurd, gave a sufficient explanation of all the celestial phenomena, and it was certainly adopted by Tycho from a thorough conviction of its truth.

The science of astronomy is indebted to the labours of the noble Dane, by his sweeping from the sky the solid crystalline spheres in which the heavenly bodies were made to revolve by the successors of Ptolemy; by his forming a catalogue of the fixed stars, to the number of 777, determining their relative and absolute positions more accurately than Hipparchus and Ulugh-Beigh; by his making many improvements in the lunar theory; by rendering the knowledge of astronomical refractions much more perfect; and by recording a vast mass of accurate observations, from which his pupil and successor, the celebrated Kepler, was enabled to arrive at those splendid discoveries in astronomy which have immortalized his name.

## JUDKINS' HEALD MACHINE.

The inventor and patentee of this machine, which was shown in Class VI., No. 52, of the Exhibition, is Mr. Judkins, formerly of Lowel, Massachusetts, U. S., but now residing at Manchester, where there is little doubt that his really useful machine will soon be duly appreciated. Its general construction is shown in figure 1. By this machine the yarn is doubled and twisted from single of itself, and, at certain intervals, is braided or plaited, so that the eye or loop of the heddle is formed without knots of any description, the whole forming one continuous line or cord. A set of healds, as made by this machine, with the eye or loop complete, is shown in fig. 2; the eye or loop is coated by means of a metallic substance, which forms also another novelty in the invention. Between the ends of the light iron frame the bed-plate is placed horizontally; on each side of the bed-plate, and let in flush with its upper surface, are ten revolving tables, each table having six slots to receive the spindles carrying the flyers and bobbins. The tables work together in pairs, and each carries three spindles, which are so set in relation to each other, that each spindle, at proper intervals, comes opposite to the vacant slot in the other table. The

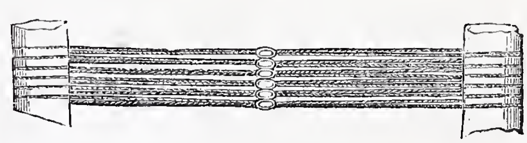
Fig. 1.



yarn is taken up from the bobbins, after undergoing the process of twisting, so as to be converted into a heddle, by two cylinders, one on either side of the machine. The working shaft of the machine is connected with the revolving tables by means of beveled wheels working underneath the bed-plate.

The machine acts as a doubling and twisting machine, except at the time when the eye or loop of the heddle is formed, when at the top and bottom of each loop it becomes a braiding machine. The bobbins, during the operation,

Fig. 2.



pass from one table to another, throughout the whole series, in a most ingenious manner. In order to show the advantage of this machine over the ordinary mode of making healds, it is only necessary to state, that from 25 to 30 sets may be produced in one working day, with the attendance of one girl, who, by hand, could only make a single set in the same time.

The assumed advantages of the healds produced by this machine are as follow:—One set will outlast fifteen sets of any other sort; more yards of cloth can be produced through them per week, and, at the same time, the cloth is more perfect, and will weigh heavier per piece, owing to there being less friction upon the warp than is usually caused by the ordinary healds.

## RYDER'S PATENT FORGE.

A specimen of this machine was shown at the Great Exhibition. Its object is to diminish the labour attending the forging of mule, throstle, and roving spindles, studs, shaft-ends, &c., for cotton and other machinery. Our drawing exhibits a front elevation of this machine. The motion is

given by means of the drum or pulley, *d*, keyed on the shaft, *e*, which is turned eccentric, thus converting its rotatory into the rectilinear motion required for the swages. Two fly-wheels, *f*, *f*, are added for keeping up a uniformity of motion. The swage-blocks, *a*, *a*, are adjusted by means of hand-wheels, *b*, *b*, keyed on the screws, *c*, *c*; they are moveable, and can be changed at pleasure, so as to suit them to the form and size of the work. The shaft, *e*, makes about 700 revolutions per minute.

This machine is described as operating more kindly on iron and steel than the ordinary method, and as forging much cleaner and with greater exactness. Its simplicity of construction, and the great saving with which it is said to be attended, are high recommendations. It is stated to be more especially adapted for articles which require drawing taper, such as files, &c., which it is estimated by the inventors to produce at one-third the usual cost.

## ANALYTICAL TABLE OF MECHANICAL MOVEMENTS.

To those who are practically engaged in the manufacture of machinery, the advantage of having portrayed the various movements which enter into the composition of our complicated machines will be sufficiently apparent. It will be particularly valuable to those whose mind is bent towards mechanical discovery and improvement. We have, therefore, been induced to give three plates of mechanical movements, which will furnish the practical mechanic and engineer with a valuable analytical table of the elements of machinery.

The idea of such a table was first suggested by the French authors Lanz and Bettancourt, who published several of the diagrams in their work. The same subject was subsequently taken up by Dr. Gregory in his work on mechanics; and an extensive table of this kind was published some years ago on a large sheet. Following up these, we have altered, added, and improved, and, we flatter ourselves, will offer a more complete and improved table than has yet been published.

### DESCRIPTION.

Figs. 1, 2, 3, 4, 5, 6, and 7, plate I., are various modifications of the pulley. The principal application of these machines is for the purpose of raising or dragging weights. No. 1. is the simple pulley which changes a downward to an upward motion; the force applied being always equal to the resistance to be overcome. By the others, which are compound pulleys, the change in the direction of the force is effected, but a greater resistance is overcome than the power applied, according to the species of pulley employed. The minute consideration of the pulley forms an important part of the treatise upon the mechanical powers; in which their principles of action, and the method of calculating their powers will be satisfactorily treated.

8. Is a parallel ruler. It is a simple ruler with small wheels of equal diameter fixed upon its ends. The circumference of tho wheels is nicked, taking hold of the paper, and keep the ruler always parallel to any lines that may be drawn by it.

9, 10, 11. Are different modifications of compound parallel rulers.

9. Is a very convenient construction. It is made by cutting a square through the diagonal, forming two right-angled triangles. This instrument is perhaps more useful than any other construction of the parallel ruler; it may be used by sliding the hypothenuse of the one upon the hypothenuse of the other, as represented, or the base of the one upon the hypothenuse of the other.

11. Is a modification by which the ends of the ruler are also kept parallel to each other. Although these instruments, as here exhibited, are used only for the purpose of drawing, the principle of their construction is taken advantage of in the formation of some parts of machinery.

12. A bell-crank lever, for changing horizontal into perpendicular motion, or *vice versa*;* frequently used for working pumps, &c.

* *Vice versa*, the other way, such as converting perpendicular into horizontal motion.

13. Is a method of keeping the carriage of any machinery parallel, and is effected by passing bands over the loose pulleys seen at either extremity of the carriage, so that the band which goes from the near low corner of the figure, is the same which is seen at the far top corner, and the reverse. The two parallel cords seen in the figure pass round other grooves in the same pulleys. When the carriage is moved backward or forward, the parallel cords move the pulleys; but the cross band preventing the one pulley from moving faster than the other, the carriage must move parallel.

14. Represents an arrangement, by which a rude press may be constructed, when only required to act through a small space. By moving the lower wedge in a horizontal direction by the perpendicular lever, the upper wedge is elevated, and presses anything placed between it and the upper beam.

15. The perpendicular rod in this figure will be alternately traversed in a perpendicular direction, by the horizontal motion of the zig-zag slot, in which the pin is placed.

16. Is a method of converting a continuous fall of water into a reciprocating motion, by means of a valve at the bottom of tho bucket, which opens by striking against the ground, and thereby emptying the bucket, which rises again by the action of a counter weight on the other side of the pulley, over which it is suspended. It may be used in raising heavy material, where a fall of water can be obtained. It has sometimes been used in iron works, in raising the material to the top of the blast furnace.

17. Is Montgolfier's ram. In this apparatus a current of water must flow through tho tube in the direction of the arrow, and escape at the valve near the right hand side of the figure, which opens inward, and is kept open by a weight on the outside, calculated according to the current, so that when the current is arrived at its speed, this valve is closed, and the momentum which the water has acquired, forces open the valve in the centre of the figure which leads to an air chamber above, where the portion of the water which has passed the valve is received, and thence conducted in any required direction. As soon as the water which passes through the centre valve has come to a state of equilibrium, the stream at the arrow is necessarily at rest, and the lower valve is again opened by the weight, at the same time that the valve leading to the air vessel is shut; thus by the alternate action of the two valves a portion of the stream is raised at every stroke, and carried to a reservoir above.

18. Represents a section of the oscillating column, invented by M. Mannoury d'Ectot, for the purpose of elevating a portion of a given fall of water above the level of the reservoir or head, by means of a machine, all the parts of which are absolutely fixed. It consists of an upper or a smaller tube, which is constantly supplied with water, and the lower or larger tube, constructed with a circular plate in the centre of the orifice, which receives the stream from the tube above. Upon allowing the water to descend, as shown in fig. 18, it forms itself gradually into a cone on the circular plate, as shown in fig. 19, which cone protrudes into the smaller tube, so as to stop the flow of water downward, and the regular supply continuing from above, the column in the upper tube rises until the cone on the circular plate gives way; this action is renewed periodically, and is regulated by the supply of water.

20. Is the hydrostatic press, as invented by Mr Bramah. In consequence of the smallness of the scale on which the figure is drawn, the pump is drawn out of proportion, to show its construction distinctly. The principle and operation of this machine will be explained in the treatise on hydrostatics. It is principally used for pressing and packing goods, or any other purpose where a great pressure is required.

21. Is an illustration of a direct rectilinear motion caused by two powers both acting in oblique directions; the one, the wind upon the sails—and the other, the rudder upon the water.

22. Is an instance of continuous rectilinear motion, producing continuous circular motion, as applied in certain descriptions of planing machines.

23. Is another instance of rectilinear producing circular motion, or *vice versa*, as used in planing machines.

24. Is a method by which rectilinear motion is converted into circular motion, by means of a rope passing round a gab-wheel. This contrivance is attached to the rope-spinner's travelling carriage, for communicating motion to the hooks used in the process of laying the strands of ropes. The lower part of the figure represents the ground plan, and the upper part an elevation of the gab-wheel.

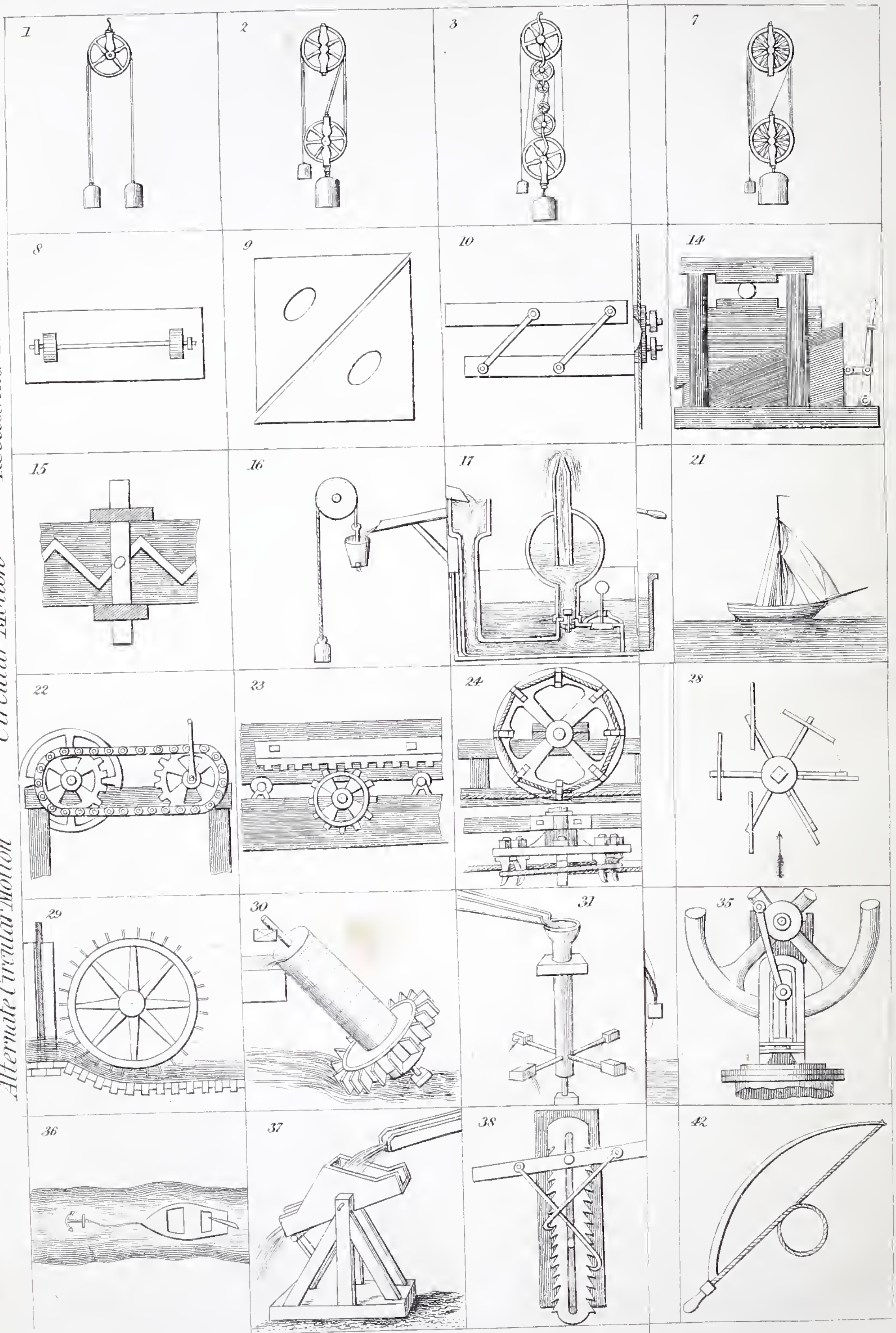
TABLE OF

RECTILINEAR MOTION CONVERTED INTO.

Rectilinear Motion

Circular Motion

Alternate Circular Motion



25. Is a construction of a ship's windlass. By the alternating motion of the lever to the right, motion is communicated to the short lever, the end of which is in immediate contact with the rim of the wheel. The lever has a very limited motion, upon a pin, which is fixed in a strong block of cast iron, consisting of two parts, each having a flange projecting inward, in contact with the inner surface of the rim. By the upward motion of the outward end of the lever, the rim of the wheel is jammed between the end of the lever and the flanges of the block, so as to cause friction sufficient to turn the wheel, by the farther upward motion of the end of the lever. The backward motion of the wheel is prevented by a common pallet.

26. A spiral wound round a cylinder will convert the motion of the wind, or a stream of water, into circular motion.

27. Shows the production of circular motion, by tho direct action of the wind upon the oblique sails of a windmill.

28. Supposing the wind in the diroction of the arrow, sails have been contrived to present the edge on returning towards the wind, and thus produce circular motion. The figure is a ground plan.

29. Is an undershot water wheel.

30. Represents an arrangement for working the screw of Archimedes for raising water. The oblique shaft of this apparatus is hollow, and is revolved by a wheel below; the hollow interior is constructed in a spiral form, which being at its lower extremity immersed in the water, takes up a portion at every revolution, and conveys it in a continuous stream to the reservoir above.

31. Is generally called Barker's Mill, and is moved by the reaction of a fall of water being allowed to escape at the extremities of the four lower arms.

32, 33. Are horizontal, overshot water-wheels.

34. Is a sectional view of the Persian wheel, said to be used in Egypt and elsewhere, for the purpose of irrigation: it consists of a hollow shaft attached to any number of floats of a curved form, at the extremity of each of which a bucket or tub is suspended. Supposing the wheel to be partly immersed in a stream of water, acting on the convex surface of the floats, a portion will be elevated by each float at each revolution of the wheel, and conducted to the hollow shaft; at the same time that each of the buckets carries its amount of water to a higher level, where it is emptied by coming in contact with a stationary pin, placed in a convenient situation for the purpose of tilting it.

35. The alternate rectilinear motion of the piston-rod of a steam engine, producing circular motion by the interposition of a connecting rod and crank.

36. This method of passing a boat from one shore of a river to the other, is common on the Rhine and elsewhere, and is effected by the action of the stream on the rudder, which carries the boat across the stream in the segment of a circle, the centre of which is the anchor, which holds the boat from floating down the stream.

37. Represents a trough divided into equal parts, and supported on an axis by a frame beneath. The fall of water filling one side of the division, the trough is vibrated on its axis, and at the same time that it delivers the water, the opposite side is brought under the stream and filled, which in like manner vibrates the trough back again.

38. The vibrating action of the horizontal lever will raise the perpendicular piece by means of the racks and catches on its opposite sides.

39. Is a modification by which the rectilinear motion of a piston-rod is converted into circular motion, as shown by the dotted lines.

40. The revolution of the wheel will produce a rectilinear motion in the bar above, by means of the studs near its circumference, acting on the piece projecting from the under side of the bar, towards the right hand. The bar is then moved to the left by the action of the studs upon one end of the bell-crank, the other end of the crank acting upon a projection upon the other side of the bar. This contrivance is used in connecting or disconnecting machinery.

41. Alternate rectilinear motion producing alternate circular motion, or *vice versa*.

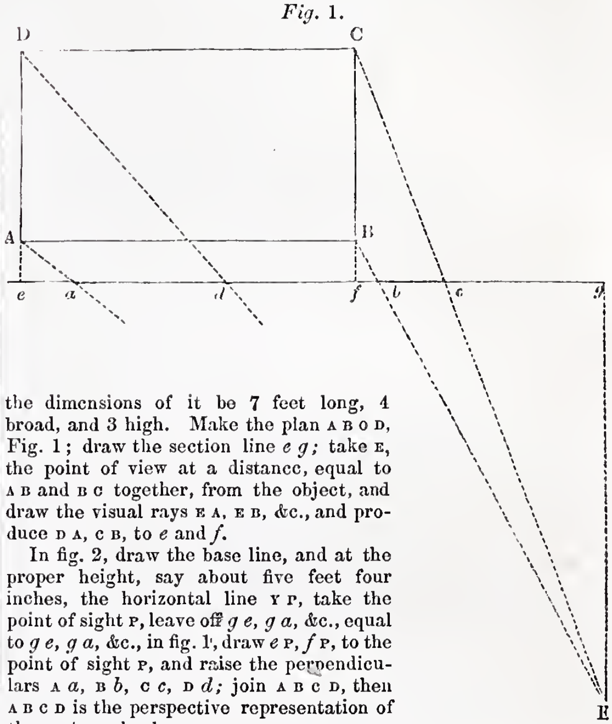
42. Is a representation of the common bow drill.

# LINEAR PERSPECTIVE.

## CHAPTER IV.

1. *To put a cube, parallelopiped, or a box in perspective.*—Let

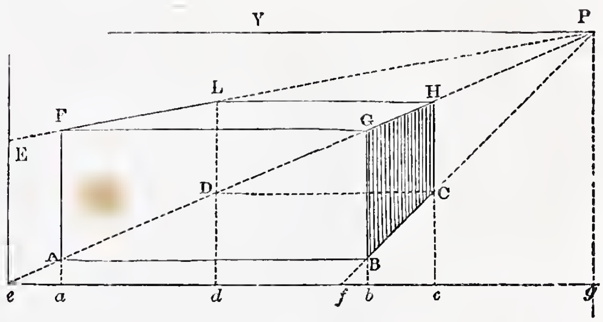
*Fig.* 1.




the dimensions of it be 7 feet long, 4 broad, and 3 high. Make the plan A B C D, Fig. 1; draw the section line $e\ g$; take E, the point of view at a distance, equal to A B and B C together, from the object, and draw the visual rays E A, E B, &c., and produce D A, C B, to $e$ and $f$.

In fig. 2, draw the base line, and at the proper height, say about five feet four inches, the horizontal line Y P, take the point of sight P, leave off $g\ e$, $g\ a$, &c., equal to $g\ e$, $g\ a$, &c., in fig. 1, draw $e$ P, $f$ P, to the point of sight P, and raise the perpendiculars A $a$, B $b$, C $c$, D $d$; join A B C D, then A B C D is the perspective representation of the rectangular base.

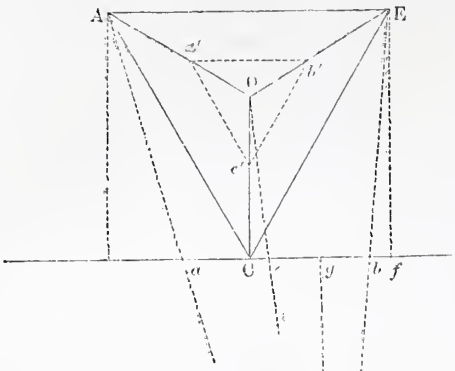
*Fig.* 2.




Here we would remark more fully what has been stated before, that whenever any part of an object touches the plane of the picture, it is made the real size; that is, with respect to tho scale by which the object is represented, and the smaller, the greater the distance from the observer. Now, a person at E, fig. 1, would see an object at D smaller than at B; but at $b$ it would be the real size, because it touches the plane of the picture. In fig. 2, $e$ E is on the plane of the picture, and perpendicular to the base line $e\ g$; if then the height of the box, three feet, be left off on $e$ E, and a line drawn to the point of sight P, the point F, where it cuts the perpendicular A F, will give A F the perspective height required, the parallel F G, and also the line G P, intersecting the perpendicular from C in H, and then draw the parallel H L; this then will give the required representation.

A perpendicular from $f$ would have answered equally as well for the height line. If the object were a cube, its perspective would be found in the same way; and if the object touched the section line, its perspective would be still more easily found.

*Fig. 3.*

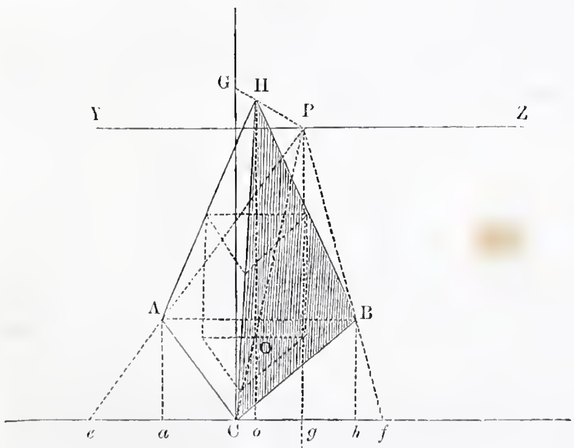



2. *To put a pyramid in perspective.*—Let it be a triangular one, each side of which is six feet, and the perpendicular height seven.

Let A B c, fig. 3, be the plan of the pyramid, o the centre, take E the point of view, and let the section line be parallel to side A B and touch the angle C, draw the visual rays, and the principal one E $g$, and the perpendiculars A $e$, o C, B $f$.

In fig. 4, let P be the point of sight, Y Z the horizontal line,

*Fig.* 4.



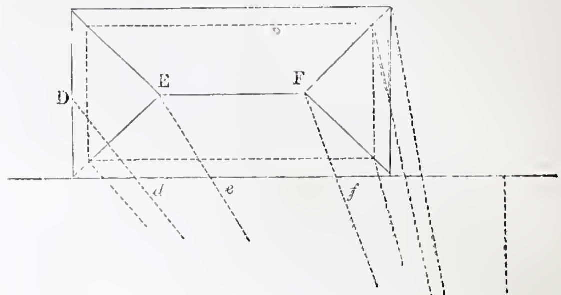

and $e\,g$ the base line; leave off $g\,e$, $g\,a$, &c., equal to $g\,e$, $g\,a$, &c., in fig. 3; and because the lines A $e$, O C, B $f$, are perpendicular to the section line, in fig. 4, they will converge to the point of sight. Raise the perpendiculars A $a$, O $o$, B $b$, and they will give the points O, A, B, the latter two of which being joined with c, gives the perspective of the base. Draw the perpendicular C G, and leave off the height on it seven feet, and draw the line G P to the point of sight P: the point H, where it cuts the perpendicular from the centre O, is the vertex of the pyramid, which being joined with A, B and C, gives the required representation. Only one side of it is seen when the point of view is opposite the middle of that side.

If A B C, fig. 3, were the plane of the base of the frustrum of a pyramid, and the dotted lines $a'\,b'\,c'$ its top, its perspective would be found by putting the small triangle in perspective, as in fig. 4, and raising perpendiculars until they would meet the lines from A, B, and O, to H, and then joining these points for the top, the base being previously formed as before.

It is evident from this, that any pyramid, whether triangular, rectangular, octagonal, &c., or any frustums of these, might in this manner be put in perspective, and also any prism.

3. *To put the block of a house in this perspective.*—In fig. 5

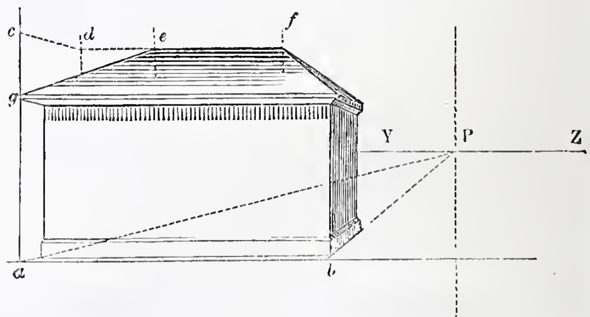
*Fig.* 5.




let the dotted lines indicate the outline of the walls, and the drawn lines the roof; the section line touches one side of the roof.

In fig. 6, P is the point of sight, Y Z the horizontal line, $a\,c$ the height line which touches one corner of the roof, $a\,b$ the base line. The roof being the most difficult part is done in the following manner:—The height, $a\,g$, to the spouting, is left off on $a\,c$, and its depth (five or six inches), and then two lines are drawn horizontal to the other side, and then from its extreme projection, which is found by plan lines, two lines are drawn to the point of sight. Now the height to the under side of the projection of the roof must be perspectively laid off, and it, together with the line of projection, and two short lines (one at $g$ to the point of sight, the other at the

*Fig.* 6.




remote corner horizontal) will show *soffit* or under side of the projection of roof. For the height, leave off $a\,c$ equal to the whole height, and run a line to the point of sight, cutting a perpendicular in $d$, which corresponds with D in fig. 5, and then a horizontal line, cutting the perpendiculars in $e$ and $f$, which points again with E and F, fig. 5, and then draw lines to the extremities of the roof. The plinth may be easily put round the two sides, and the rest of it is easy.

In the next chapter, the circle put in perspective will be the chief thing.

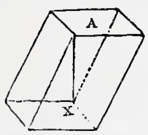
# NATURAL PHILOSOPHY AND CHEMISTRY.

## CHAPTER XII.

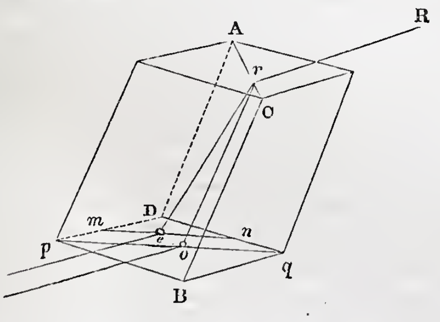
### ON THE POLARIZATION OF LIGHT.

The law relating to the passage of light through uncrystallized media, is by no means general. It is indeed true for a large class of refracting substances—for all gases and vapours, for all liquids and bodies solidified from the liquid state, so suddenly as not to admit of regular crystalline arrangement, such as glass, gums, jellies, resins, and the like, and for a numerous class of crystallized bodies, whose primitive crystals have three precisely similar axes, as the cube and regular octohedron; and which may therefore be considered to be constituted of spherical particles, whose action upon light passing through them is uniformly the same, in whatever direction it may go. In all media of this kind there is only ordinary refraction and a single image, provided the bodies have the same density throughout, and are neither compressed nor dilated by mechanical force, nor the unequal action of heat. But in almost all other transparent bodies, including salts, crystallized minerals, all animal and vegetable bodies in which there is a tendency to regularity of structure, as horn, quill, hair, shells, mother-of-pearl, certain leaves, stalks, and seeds—all such bodies act upon light in its passage through them in a very different manner. They refract it into *two different portions*, differing from each other in their physical properties, and more or less inclined to each other according to the nature of the body, and according to the direction in which the light is incident. The separation is sometimes very great, and, in most cases, easily observed and measured; but, in other cases, it is not visible, and can only be inferred from certain effects which accompany this *double refraction*.

The best exemplification of this mode of refraction is obtained in that variety of crystallized carbonate of lime called Iceland spar. This mineral is perfectly transparent, and generally colourless; and is, moreover, susceptible of a high polish. It is found, in almost all countries, in crystals of various shapes, and often in huge masses; but in whatever form it is found it can always be divided into shapes like that represented on the margin,—a figure called a rhomb, and is bounded by six equal surfaces, whose opposite sides are parallel, and whose angles are 101° 55′ and 78° 5′. The line A X joining the obtuse angles, is called the axis of the crystal.




Having procured a rhomb of Iceland spar, like that represented, with smooth and well-polished faces, and so large that one of the edges is at least an inch long, let one of its faces be placed upon a slip of paper having a sharp black line drawn upon it; in certain positions the line will appear double; and, upon turning the rhomb round in its own plane, so as to make a complete revolution, the two lines will assume a regular movement with regard to each other: they will coincide twice in the revolution, and it will be easy to ascertain that these coincidences take place in two positions of the crystal, which are directly opposite to each other. The arrangement is shown in the annexed figure—the line appearing double as




*m n* and *p q;* or a dot will, under the same circumstances, appear double as *e o*. Hence, it appears that the ray of light R *r*, falling upon the surface of the spar, is divided into two rays, *r e* and *r o*, and it is therefore said to be *doubly refracted.*

If we look through the crystal at any large object, the image is similarly doubled, and presents the same phenomena of lateral removal and coincidence; the only difference being that they encroach upon each other and do not present a complete separation. This is, moreover, true, whether or not the eye looks directly at the face of the rhomb. With a circle traced on paper the phenomena are very distinct, the circular images appearing entirely separate, or one overlaying the other, according to the magnitude of the circle viewed, and the thickness of the crystal.

If we examine the circumstances of this experiment very narrowly, we observe that the portion *r o*, of the ray R *r*, obeys in every respect the ordinary law of refraction, which we have already explained, (Vol. I. p. 257,)—it is therefore denominated the *ordinary ray;* but the other portion *r e* deviates from that law, inasmuch as the lines of incidence and refraction cease to have the constant relation to each other which the law requires; and it is accordingly distinguished as the *extraordinary ray.* These facts are readily verified by turning the crystal round about some vertical axis; during the operation the extraordinary image appears to revolve about the ordinary in a circle, but coincides with it twice during the revolution of the rhomb, and at these points of coincidence we observe that the light passes through the crystal in the direction of its axis, and the point of greatest deviation is when the light passes at right angles to the plane of the axis.

In some bodies there are two directions, along which objects viewed through them appear single; they are, therefore, said to have *two axes* of double refraction. In the case of Iceland spar, and many other minerals, there is only a single axis of double refraction, namely A X. This axis is not, however, like the axis of the earth, a *fixed line* within the crystal: it is only a *line of direction;* for, if we divide the rhomb into any number of smaller rhombs—which can readily be done—each of these will have its axis of double refraction; but when they are all put together again, their axes will all be parallel to A X. Every line, then, within the rhomb, which is parallel to A X, is an axis of double refraction, and it is only because these have one and the same direction in space, that the crystal is said to have only one such axis.

To examine somewhat further the nature of the light which is separated in passing through a rhomb of Iceland spar, let it be made to traverse another crystal of the same mineral; if this second crystal be placed symmetrically with the first, the axes being parallel, there is no further subdivision of the light, the images are merely separated to a greater distance on account of the greater thickness through which the rays pass; and again, if the crystals be so placed that the planes of their axes are at right angles to each other, there will still be but two images. But, in this case, it may be observed, that the ray, ordinarily refracted in the first, becomes extraordinary in the second, and the extraordinary ray becomes the ordinary. At all intermediate positions of the crystals there is a subdivision of each ray, and, consequently, four images. These four images are of equal intensities when the planes of the axes of the two crystals are at an angle of 45° to each other; at all intermediate positions the images possess very different intensities, fading and utterly disappearing as the axes approach to parallelism.

From these phenomena, it then appears that each ray emerging from a crystal of Iceland spar, is subject to further division only in certain positions of a second crystal; when the principal planes of the rhombs coincide, and when they are at right angles there are only two images, and in every other position there are four, and these properties are similar, provided we suppose one pencil to be turned through an angle of 90°. When the planes of the axes coincide, the ordinary ray produces only an ordinary ray; but, when these planes are at right angles, the extraordinary ray produces an ordinary ray, and the ordinary ray an extraordinary ray. It thus appears that the properties of the pencils of light have relation to the principal plane of the crystal, and whatever properties the ordinary ray may possess with respect to that plane, the extraordinary ray possesses the same properties with respect to a plane at right angles to it; for each acquires the property of the other when the change here indicated has been made in the position of this plane.

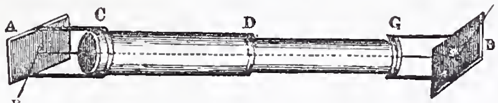
It was these facts which suggested to Sir Isaac Newton the idea that a ray of light has *sides* or *poles*—that is, some distinct

relation to surrounding space; and the manner in which that philosopher announced the phenomena, has since given rise to the term *polarization*—which, in the language of modern science, is used to express the properties possessed by each ray with respect to particular planes. Thus, the ordinary ray has properties with reference to the principal plane, and the fact is expressed by saying that it is polarized in the principal plane of the crystal. And again, the extraordinary ray has properties with reference to a plane at right angles to the principal plane, and the fact is expressed by saying that it is polarized in a plane perpendicular to the principal plane of the crystal.

It must not, however, be thought that the phenomena of polarization are the effects of any polarizing force residing in the crystal. The whole series of experiments on the subject leads to the conclusion that polarization is not an alteration of the properties of light, but that common light is of such a nature that it may be separated into two portions by the refracting power of the crystal, just as it is separated into its coloured elements by prismatic refraction. This is rendered clear by the circumstance that the reunion of two oppositely polarized beams produces common light, in the same manner as the reunion of the colours of the spectrum produces white light.

Refraction is not, indeed, the only mode by which light is polarized. If it be reflected from any surface at a particular angle—differing for different substances—it undergoes polarization, and is said to be polarized by reflection. Indeed, in all cases of reflection there is some light thus modified, some portion of it falling upon the reflecting surface at the required angle, and at other angles a portion of it is polarized, in degree, according as its angle of incidence approaches the polarizing angle on either side.

The phenomena of polarization by reflection may be conveniently shown by means of an apparatus like that here figured,



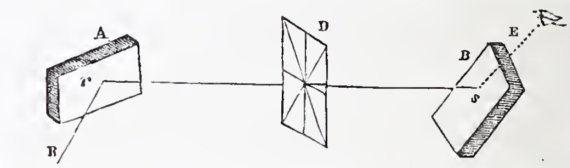

in which C D is a brass tube, having at one end of it a plate of glass A, blackened on the external surface, and capable of turning round on an axis, so that it may form different angles with the axis of the tube. D G is a similar tube, but of a smaller diameter than the other, and carrying also a glass plate B. The tube D G may be pushed into the other C D; and by turning the one or the other round, the two glasses may be brought to any position with regard to each other. Supposing these reflectors fixed at an angle of 33° with the axis of the compound tube, let a ray of light R *r*, from a candle or a hole in the window-shutter, fall upon it, and adjust the apparatus to such a position that the ray shall be reflected along the axis of the tube. The tube which carries A is then fixed, leaving that which carries B moveable within it. The light which is reflected from A, after traversing the axis of the tube, will fall upon B, and be again reflected. It may then be received by the eye or upon a screen. The whole being thus arranged, let the tube D G be turned round within C D, carrying with it its reflector B, which, in its revolution, will always preserve the same inclination to the axis of the tube. But if we attend to the light reflected from B, it will be observed in the course of the revolution constantly to vary in intensity: at two opposite points it will acquire a maximum intensity, and at two other opposite points, intermediate between these, it will entirely disappear. On comparing the positions of the reflecting planes at the concurrence of these phases, it will be found that the intensity of the light is greatest when the planes are parallel, and that there is no reflection when the planes are at right angles to each other. It thus appears that a ray of light reflected from the surface of glass, at this particular angle of 33°, is incapable of being reflected a second time from a similar surface perpendicular to the former at an equal angle of incidence. It has in fact ceased to be subject to the ordinary law of reflection in a perpendicular plane, at the same time that it preserves its property of being reflected in the same plane.

If a plate of tourmaline be substituted for B, the light from A will be absorbed or transmitted according to the position which the axis of the crystal, from which the plate was cut, bears to the reflecting plane. If this axis be parallel to A, the whole of the reflected light will be transmitted through the plate; but if the plate be turned round in its own plane until the axis becomes perpendicular to the reflecting plane, no portion of the light will be transmitted.

Although all reflecting bodies are capable of polarizing light, if incident at proper angles, metallic bodies, and bodies of high refractive power, like the diamond, appear to do so imperfectly,—the reflected ray not entirely disappearing in circumstances where a perfectly polarized ray would be entirely extinguished. As already stated, bodies have each their particular polarizing angles. Thus, in the case of glass, we observe that the angle which the direction of the ray must make with the reflecting surface is 33°—that is, the angle of incidence (the complement of this) is 57° in round numbers, and it is this last which is called the *polarizing angle*.

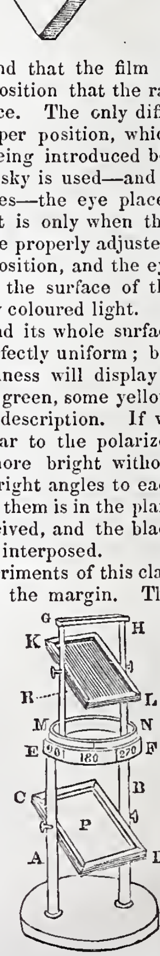
| | | | |
|---|---|---|---|
| For glass it is . | 56° 45′ | For Iceland spar it is | 58° 51′ |
| Water, . . | 53° 11′ | Sulphur, . . | 63° 45′ |
| Quartz, . . | 56° 58′ | Diamond, . | 68° 1′ |

The most interesting, and by far the most splendid phenomena which are afforded by polarized light, are the vivid and gorgeous colours developed by the transmission of light through transparent plates that possess the power of double refraction. If a ray which has been polarized in any of the ways described, be made to traverse a thin plate of mica, which is perfectly diaphanous and colourless to common light, be received upon a plate of glass in a particular position, the ray will appear coloured in the most splendid manner with different tints, depending upon the thickness of the plate and its inclination. The arrangement of this experiment is here depicted. Suppose the reflectors to




be the same as those formerly described, and that the film of mica D is placed between them in such a position that the ray from A falls perpendicularly upon its surface. The only difficulty is to place the reflectors in the proper position, which must be done previous to the film of mica being introduced between them. Supposing that light from the sky is used—and it will answer sufficiently well in ordinary cases—the eye placed at E should observe a black spot at *s*, and it is only when this spot appears that the apparatus is known to be properly adjusted. The mica may then be introduced into its position, and the eye placed at E; looking in the direction of E *s*, the surface of the mica will appear to be illumed with brilliantly coloured light. If the film be perfectly uniform in thickness, and its whole surface perpendicular to the ray, its tint will be perfectly uniform; but if it have different thicknesses, every thickness will display a different colour—some red, some blue, some green, some yellow, others violet—and all of the most brilliant description. If we turn the film round, keeping it perpendicular to the polarized beam, the colours will become less or more bright without changing their nature, and two positions at right angles to each other will be found, such, that when either of them is in the plane of reflection, no colours whatever are perceived, and the black spot at *s* will appear as if no mica film were interposed.

The most convenient mode of making experiments of this class is by means of the instrument depicted on the margin. This instrument was first suggested by M. Biot, and may be conveniently termed a *polariscope*. It consists of two uprights of wood A B inserted into a sole, and supporting a frame C D, constructed like a common looking-glass frame. A circular plate of wood E F rests on the pillars, and has a circular aperture in the middle, about three inches in diameter; a ring of wood M N, moveable round a circular projection on E F, supports two pillars G H, between which rests, by means of screws, a frame K L like C D, but somewhat smaller. A circular slip of paper graduated into 360° is fixed on that portion of E F which projects beyond M N, a black line being marked on the latter, to serve as an



index and point to zero on the graduated paper, when the pillars G H are exactly over A B, and the frame K L similarly placed with regard to C D. A plate of glass rests over the aperture in the centre of E F to serve as a stage, on which objects to be submitted to the action of polarized light are placed. Into each of the frames C D and K L are fixed smooth panes of glass P and R, covered on the back with opaque black paint—as lampblack and size. It is the uncovered surfaces, of course, which are exposed to the action of the light, and the painted sides may be protected by pieces of blackened wood or pasteboard. The polariscope is then complete, and all the experiments on polarization described above may be performed with it in the most convenient manner.

It may be mentioned that, in speaking of the plates, the plate R is always termed the *analyzing plate*, because its use is to analyze, or separate into parts, the light transmitted through any body that may be placed upon the stage of the polariscope between the eye and the *polarizing plate* P, the use of which is to furnish us with a broad and bright beam of polarized light by reflection.

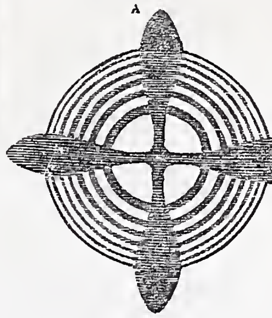
In using the polariscope, the source of light may be the sun's rays, diffused day-light, or still better, the light of a lamp or candle, provided with a tissue-paper or ground-glass shade. Supposing the reflector P properly adjusted, to make the light reflected from its surface, to traverse the axis of the instrument, till it meets R; and suppose that the index on M N is placed at zero of the graduated circle E F; if a film of selenite be placed on the stage, its image at R will be seen of a tint varying with the thickness of the film. If it be slowly turned round, the colour will gradually diminish in brilliancy, and ultimately vanish. Continue to turn it round, and the colour will gradually reappear, and attain finally its primitive brilliancy. Continuing the rotation, the colour again lessens and disappears. There are thus two points in the revolution of maximum brilliancy, and two where no colour is perceived; and as in the description of the former experiment, we find that the planes of these points—the point of greatest intensity, and the vanishing point—are inclined to each other 45°.

Again, supposing the instrument adjusted, as at the beginning of the experiment, let the film of selenite be fixed; and suppose its thickness to be such that its tint appears red; when its red image is visible in the analyzing plate, slowly revolve the latter, noticing the arcs of rotation on the graduated circle. It will be observed, that the red colour of the reflected image gradually lessens, and when the analyzing plate has moved through an arc of 45°, it will disappear—by continuing the rotation the film will gradually assume a green colour, complementary to the red, and will attain its greatest brightness at 90°. Through the next arc of 45° the green vanishes, and 135° being passed, the red reappears, attaining its most vivid state at 180°. The same phases are repeated during the succeeding motion through arcs of 45° till the whole revolution is completed, when the image is red as at first. If the selenite be taken at such a thickness, as to afford other tints, the complementary colours will still be found; that is, the colours at 0° and at 90°, or at 180° and 270° will be invariably such, that being united, they would constitute white light.

From this combined experiment—and it is only one of a class—it then appears, that when the film alone revolves, only *one colour* is seen—the film being of uniform thickness—but when the analyzing plate revolves, *two colours* are seen during each half of its revolution.

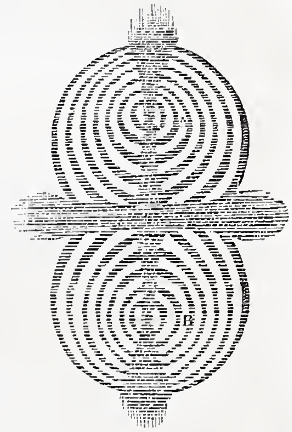
The action of polarized light, is, if possible, still more interesting, in the evidence which it gives of the internal constitution of crystals of the different systems. If a rhomb of Iceland spar, with the apices of the obtuse angles terminating its axis cut off, and the triangular faces thus left polished, be placed on the glass stage of the polariscope, which for this purpose should be brought as near as possible to the analyzing plate, and a beam of polarized light be transmitted through it, a beautiful series of coloured rings, intersected by a black cross, will appear when the planes of the analyzing and polarizing plates are at right angles to each other, the index on M M being at 90°. The colours are the same as those in Newton's table, and consequently the same as the system of rings seen by reflection from the film of air, between a lens and a flat plate of glass. If we turn round the analyzing plate, so that the index may be at 0° or 180°, these rings will be replaced by another set complementary to them, and the black cross by a white one. These phases are represented by A and B.

A

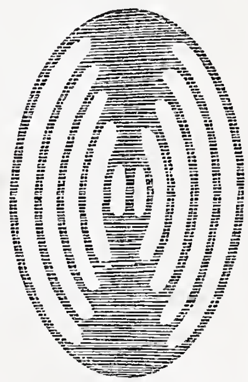


B

If the crystal belong to any of the more complex systems—that is, have two axes of double reflection, as nitre, topaz, sulphate of nickel, carbonate of soda, and the like—a double system of rings is visible, when polarized light is transmitted; these rings uniting, form a beautiful curved figure, such as is represented in the margin—which is the appearance seen with nitre. The curves are crossed by two bands, which are black or white, according to the position of the analyzing plate; but the systems of rings open out, and each revolves on its axis when the crystal is made to turn round on its principal axis.



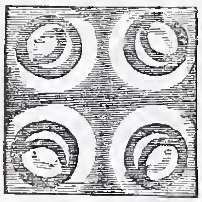
In various crystallized bodies, as topaz, carbonate of soda, where the inclination of the resultant axes, A and B, is large, the two systems of rings cannot at once be seen; we can only see one of the systems, that is, one half, or the portion round one axis. The annexed figure is the appearance exhibited by a plate of topaz, made by polishing two parallel faces, perpendicular to the axis of the rings.



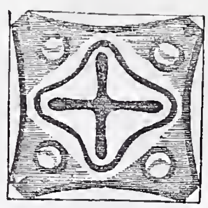
By means of the property possessed by polarized light, of developing these coloured rings, which always in tint and arrangement bear a constant relation to the physical structure of the crystal producing them, we are enabled frequently to make out the existence of peculiar and intimate arrangement of molecular structure, and thus acquire a new and powerful mode of investigating the internal arrangement of some of those simple but wonderful structures presented to us so liberally in both the organic and inorganic world. This may be beautifully illustrated by subjecting unannealed glass to the action of polarized light. Glass, by suddenly cooling from a red heat, acquires the property of double refraction. Such a piece of glass appears, when examined by ordinary light, like any other piece; nor can any peculiar feature be detected in it, in which it differs from any other specimen of that substance. But if the prepared specimen be laid upon the stage of the polariscope, a most beautiful coloured image will become visible in the analyzing plate; whilst under similar circumstances, the glass before heating, did not exhibit the slightest colour. Let the planes of the analyzing and polarizing plates be at right angles, the index being at 90°, and if the glass be shaped into a cube, the beautiful figure shown at A will appear. The circular curves in the angles possess the most vivid hues, in which red and green predominate, the centre being occupied by a black

cross. On turning the analyzing plate round 90°, so that the planes of reflection and polarization may coincide, the colours,

A

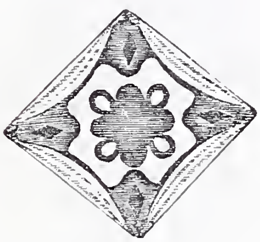


B

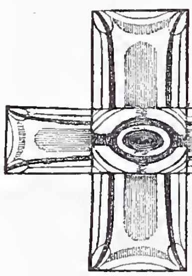


which almost entirely vanished at 45°, will undergo a most remarkable change; the image will appear with all its colours complementary to those of the first image A, and the black cross replaced by white spaces. If the piece of unannealed glass have a breadth only one-third of its length, the image formed, will be that shown at B, when the analyzing plate is at 90°. If the analyzing plate be fixed, and the unannealed glass be slowly turned round, the black cross will begin to appear, and its arms to separate in elegant curves, until its resultant axes are inclined 45° to the planes of polarization and reflection, when the beautiful symmetrical figure C, will appear. Again, if two slips of the same substance be laid across each other, we shall have such a figure as D.

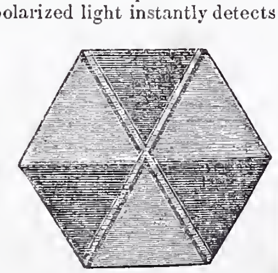
C

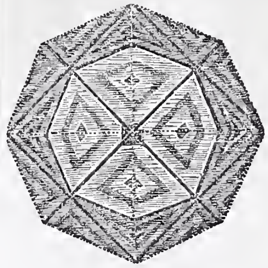


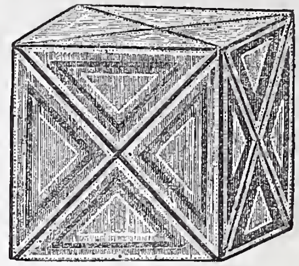
D



When crystals form in a confused manner, it often happens that not only their surfaces are modified in a complicated manner, but several crystals become soldered together so compactly, as to simulate a form which does not belong to the substance of which the crystal is composed. These crystals are called *macles*, and some bodies have a remarkable tendency to be crystallized in this way. Thus, sulphate of potash was long considered to crystallize in six-sided prisms, terminated by six-sided pyramids; but by optical examination, we find that this figure is composed of three true crystals which are right rhombic prisms. These being laid together form, by their angles exactly joining, a six-sided prism. If a plate be cut out of such a compound crystal, the eye will not be able to distinguish it from a plate cut out of a single crystal; but exposure to polarized light instantly detects its composite nature, and exhibits to the eye, the very lines of junction. In place of the system of rings, we have the tesselated structure of the figure. A very beautiful illustration of this macled form, is afforded by the mineral called *analcime* and *cubizite*. The first of these names was given to it by Haüy, on account of its yielding no electricity by friction; and it has obtained the name of *cubizite*, because the mineralogists believed the cube to be the form of its primitive crystal. It has however no cleavage planes, and in this respect must be regarded as great an anomaly in crystallography as it is in optics. When a cube of it is examined by polarized light, the image displays the most beautiful colouring which can be imagined. The annexed figures give some notion of the arrangement of the tints. The diagonals become occupied by lines which are alternately black and white, according as the analyzing plate is made to revolve, and in the intervening triangular spaces, the richest colours of the rainbow succeed one another in strict harmony. The distribution shown in both figures cannot of course be exhibited to the eye at once, but are deduced by transmitting polarized light in every direction through the mineral.







This optical examination leaves no doubt that the crystal is made up of a great number of other crystals, belonging to some one of the more complex systems; but the true structure of the mineral is so extraordinary, that the form of its primitive crystal has not yet been determined.

The phenomena described are not only presented by regularly crystallized bodies and unannealed glass. Mechanical action is capable of developing the same property in several other substances. Thus, the bending of a slip of glass will make it act upon polarized light in the same manner as a crystal of Iceland spar, at the part of greatest tension; and a mass of jelly, compressed between two slips of glass, and placed upon the stage of the polariscope, will give a series of tints traversed by a black cross, provided the analyzing plate be so placed that the planes of reflection and polarization are at right angles. Jelly, solutions of gum, and albuminous fluids, allowed to evaporate spontaneously, so as to leave an indurated mass, all exhibit the same phenomena; and no series of tints from polarized light are more beautiful than those produced by the crystalline lenses of animals, especially fishes. Fragments of quills, horn, hair, and other indurated animal structures, also exhibit these tints in great brilliancy.

There is one more class of phenomena to which we would briefly refer. If a thin uniform plate of rock crystal be cut in a direction perpendicular to the axis of the crystal, and placed on the stage of the polariscope; on looking into the analyzing plate, no black cross will be visible as in Iceland spar; but a few rings will be seen at the circumference of the image, and the centre filled up by a uniform tint depending upon the thickness of the plate. If this central colour be red, move the plate slowly round, and it will successively change to orange, yellow, green, and ultimately to violet, as though the analyzing plate had during its rotation acquired the power of reflecting these different colours. In some specimens of the mineral, the colours change from red to violet when the analyzer is turned from right to left; and in others, when it is moved from left to right. Hence, we have what are from this fact termed right-handed and left-handed quartz, and the phenomena described constitute what is called *circular polarization*. The polarized light is in this experiment affected, as if it passed through the quartz, and were resolved into a series of homogeneous rays, disposed in planes radiating from the centre of a circle like the rays of an expanded fan. The arc of rotation occupied by each colour—that is, the arc through which it is necessary to move the analyzing eye-plate, in order to convert one image into one of a different tint—increases with the thickness of the quartz plate. Thus, suppose we place a plate of quartz upon the stage of the polariscope $\frac{1}{25}$inch thick, and suppose we examine it by polarized red light—which we readily get by passing the common light before it falls upon the polarizing plate, through glass coloured red, by protoxide of copper—the space in the centre of the rings will be brightest when the index is at 90. If we move the analyzer from right to left, through $17\frac{1}{2}$°, the red tint will cease to be visible: with a plate of double thickness, a rotation of 35° would be required to produce the same effect.

This property of quartz was, on its first observation—which we owe to M. Biot—thought to depend upon its crystalline structure. But the discovery of the same property in some liquids soon after, caused that opinion to be abandoned: and the phenomena having been now pretty extensively examined, the settled conclusion is, that the power of circular polarization does not depend upon the manner of molecular aggregation, but involves the chemical nature of the molecules of which the body

is composed. In the hands of the chemist, it is indeed rapidly passing to be one of the most certain and convenient of his means for distinguishing between closely allied organic products. Thus, to point out a beautiful application of the principle, in the changes which occur during the saccharine fermentation—a solution of starch possesses a high rotative power from *left to right;* but it gradually changes into sugar of grapes, the rotative power of which is from *right to left.* These properties are expressed symbolically by an arrow pointing to the right or left, according as it is necessary to make the analyzer of the polariscope revolve to the one or other side. When the fermentation has commenced, the action of the starch rapidly diminishes, until there is so much sugar formed, that → and ← exactly balance, and the solution produces no effect upon a polarized ray. This point being attained, the sugar continues still to form, and the rotative power is changed to ← and increases in numerical value—that is, the arc of rotation becomes greater—until all the starch has been decomposed; and knowing the quantity originally employed, the measure of its rotative power enables the quantity of sugar present to be at once calculated. The juices of plants employed in the manufacture of sugar, as that of beet-root, maple, the sugar-cane, may all be readily and accurately valued by a simple determination of their rotative power in relation to their specific gravities. M. Biot has already applied circular polarization to purposes of this kind, and thereby connected one of the most recondite principles within the range of physics with the practical arts, and conferred upon it a commercial importance, which will speedily make it known in every sugar-house and brewery throughout the world.

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We cannot in the mean time enter upon the explanations of the optical phenomena described in this paper, but shall return to the subject. In the mean time, we may refer those who are anxious for a more full discussion of the subject, than our pages will allow, to Sir David Brewster's Treatise on Optics (Cabinet Cyclopedia), and Dr Golding Bird's Elements of Natural Philosophy.

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## MECHANICS.

### PART II.—ELEMENTS OF MACHINERY.

### CHAPTER II.

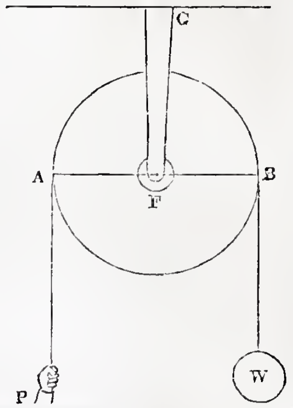
#### THE PULLEY.

Though the elements of machinery are stated to be six in number, they are reducible, on general principles, to two—the lever and the inclined plane. What we mean is, that though they vary essentially in the particular arrangement of their parts, yet they may all be resolved into two general principles of action which are most simply represented in the action of the lever, and of the inclined plane. Thus the pulley and the wheel and axle are directly modifications of the lever, and their action may be calculated on its principles; and the wedge and the screw are in like manner modified inclined planes. As has already been explained, the principle of the equality of moments is that on which the action of the lever is founded, and it supposes a centre of motion, while the action of the inclined plane, as will afterwards be seen, is a case of the composition and resolution of forces by the triangle, and does not imply any centre of motion; so that the existence and non-existence of a centre of motion, are the distinguishing characteristics of the two general elements of machinery.

In ordinary cases of the lever where the motion round a centre is required only through a small space, the ordinary beam or bar does sufficiently well, as in the instance of the pump-handle, the weighing beam, and the more complex cart weighing-machine, already described. But when a continued motion is required to be transmitted from one centre to another, there must be a constant succession of levers working on the two centres, and coming by successive pairs into contact. In short, wheels with teeth on their rims, usually named spur-wheels, are just systems of levers such as these now referred to, and by working into one another communicate a continued rotatory motion from one centre to another.

A wheel with a plain groove in its circumference for the reception of a rope or chain forms a *pulley,* and its office, when fixed by the centre and used singly, is to change the direction of the rope or chain employed in raising weights or overcoming other resistances, for the more convenient application of a given power.

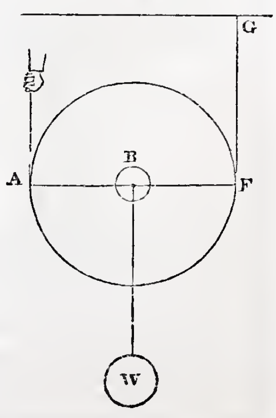
For example, in the annexed figure the pulley is staid at the centre, F, by the bracket F G, to the surface above; the weight is drawn upward by the downward force of the power P, which is connected to it by a rope passing over the circumference of the pulley. The centre, F, of the pulley being fixed by the stay, F G, is also the centre of motion, and therefore if lines be drawn to it from the points A, B, at which the rope leaves the pulley, these lines A F, B F, being the distances from the centre at which the power and the weight act, do virtually form a lever by which the former acts on the latter. And as A F, B F, are of equal lengths, they form a lever of equal arms, and, therefore, also the power and the weight are equal. From this, we see that the simple fixed pulley operates neither as a concentrator nor as a diffuser of force, but simply transmits the force employed and changes its direction. In the course of one revolution, every point in the circumference will arrive at the positions A, B, and so in its turn be the extremity of a lever consisting of two radii. Thus the pulley is virtually composed of a great number of levers with equal arms successively brought into action when the pulley is in operation.




It is not essential to the character of the fixed pulley that the power and resistance act by it in the same direction. In the bell-crank—and the greater part of the various contrivances employed in bell-hanging may be referred to the fixed pulley—we have an example of its use, in changing the direction in several different angles. In cases of this nature, the pin upon which the crank moves represents the fulcrum, and the radial arms of the sector answer directly to the arms of the bent lever.

It is seen, then, that the single fixed pulley is a universal lever of the first kind, the centre of the pulley being the fulcrum. The pulley, however, may also be employed as a lever of the second and the third kinds by altering the circumstances.

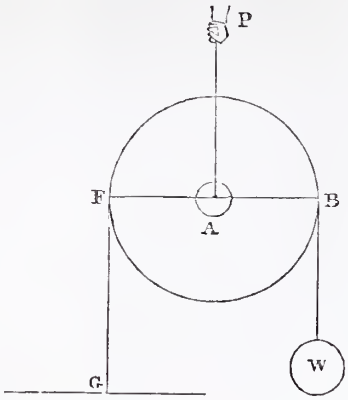
The second kind of lever is that in which the resistance is between the fulcrum and the power. To show that this condition may be fulfilled by a pulley, let the weight W be suspended by the centre B. Take A B as before, then one end, F G, of the rope, being fixed at G, and the power applied at the other end A, the point F will be the fulcrum of the lever, and the power being applied at A, the distance A F is twice the distance B F. As the power, therefore, acts at double the distance that the weight does, from the fulcrum, it will be only one-half the weight, and thus equality of moments is produced; that is, $P \times AF = W \times BF$. Thus the single moveable pulley enables a given force to



overcome a resistance of double magnitude; in other words, a power of 1 lb. is sufficient to balance a weight of 2 lbs., when suspended from the axis of the pulley.

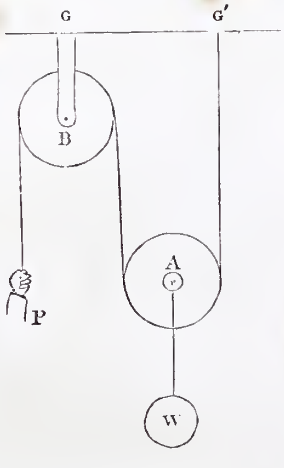
From this, then, we observe, that while the fixed pulley is nothing more than a lever of the first kind, with equal arms, the moveable pulley is a lever of the second kind, in which the resistance to be overcome is at an equal distance from the fulcrum, and point of application of the power.

But, again, the pulley is applicable as a lever of the third kind, in which the power is applied between the fulcrum and the weight. For, by passing a rope over the pulley and fixing it below at G, with the weight W at the other end, and applying the power at the centre A; it is evident that F is the fulcrum, and that the distance of the power from it is just one-half of that of the weight; that is, $AF = \frac{1}{2} BF$, consequently it must be of double magnitude to balance it. Now, these three are all the varieties of application of a single pulley in overcoming resistance; and in these it exactly coincides with the three kinds of levers already described.

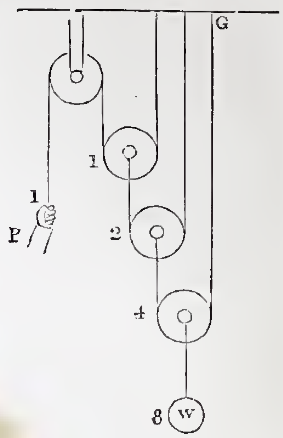



It is to be observed, also, that, in all the three cases, the pressure acting on the centre of the pulley, being between the other two at the circumference, is always opposite to them, and equal to their sum. And, moreover, it is clear that the pressures at the circumferences must be equal to one another, since they are acted upon by equal forces. From this principle which has been before referred to, the relation of the power to the weight in single pulleys might have been deduced, and it will be useful for reference in the succeeding part of this paper.

We shall now examine the various advantageous combinations of pulleys into systems, and it is in these that the great use of the pulley is to be had. The application of the pulley to the purposes of a lever of the third kind, is rarely if ever made in practice; so that all systems are composed of the first and second kind. The annexed figure shows a simple combination of the two, in which there are two fixed points G, G′, serving as fulcra for the pulley A of the second kind, and the pulley B of the first kind. The pulley B simply returns the rope downward for the convenient application of the power, and A enables a power of one-half to overcome the weight suspended. For, the sum of the pressures upward on A is equal to the weight W; that is, each is one-half, so that the pressure at G′ is one-half W, and that at the circumference of B is also one-half. And, again, as the extreme pressures on B are equal, the power, P, must also be one-half, W, while the force at G is equal to W. It is seen too that the whole pressure on the sustaining points of the system is equal to the sum of the pressures acting in the system; that is, the pressures sustained by G and G′ are equal to the force P and twice P which is W.

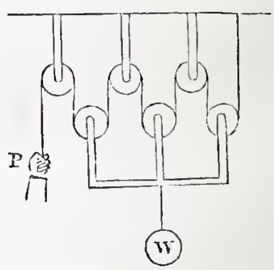



The effect of this kind of machine is increased by the addition of moveable pulleys as in the figure annexed, where there are three pulleys with three ropes fixed at one end, and connected at the other with the pulleys above. Thus a weight, W, of 8 lbs. hanging by the lowest pulley is divided between the two parts of the rope sustaining it; in this way producing a pressure of 4 lbs. on the centre of the second pulley. This pressure is in like manner divided between the two parts of its sustaining rope, and a strain of 2 lbs. comes on the centre of the third pulley, giving a force of 1 lb. on one side of the fixed pulley, and the same of course on the other side, for the power necessary to raise a weight of 8 lbs. by the system of pulleys described.

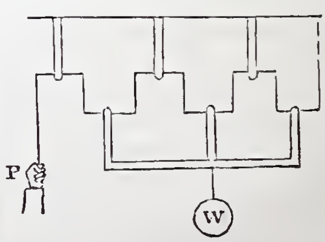



It appears, then, that by such a system of pulleys, the power necessary to balance a weight suspended from the lowest, is found by dividing it by 2 as often as there are moveable pulleys; or, which is the same, take that power of 2, of which the index is the number of moveable pulleys, and divide the weight by it. The quotient is the power that will balance the weight. In this instance, there are *three* moveable pulleys; we, therefore, take the *third* power of 2, which is 8, and dividing the weight W, which is 8 lbs., by this number, gives us a quotient of 1 lb. for the power.

But the idea may be still farther improved upon; for, if instead of providing independent ropes for each moveable pulley, and fixing them separately, we carry a single rope over a series of fixed and moveable pulleys, as shown in the figure, and let the weight hang from the three moveable pulleys by their centres, these being set in a frame for the purpose; then the three fixed pulleys, alternate with the three moveable ones, and to the bearing frame of the fixed pulleys is attached the one end of the rope, which passes over and under all the pulleys; and, thus, when the power is applied at the other end, so as to produce equilibrium, what is the state of things? The weight is divided equally between the three lower pulleys, one-third hanging by each of their centres. The upper pulleys merely conduct the rope from one to another of the lower ones, among which alone the advantage is had. These pulleys hang by six cords from the upper ones; therefore each cord must bear one-sixth of the whole weight, so that if the weight be 6 lbs., a power of 1 lb. at the end of the rope will manifestly maintain the equilibrium.

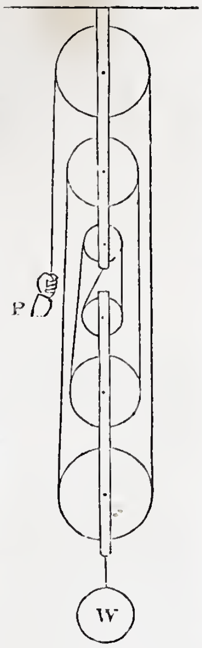



The similarity between this disposition of pulleys, in regard to their mutual action, and systems of levers, acting by contact, (such as those figured on page 359,) is to be remarked. By substituting levers for the pulleys, as here sketched, the rationale of their action on one another becomes very obvious. The ends of the levers, as they are at some distance from one another, are connected by cords which distribute the pressure among them.



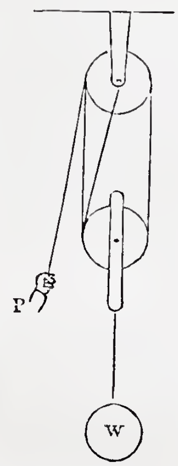

Another arrangement of fixed and moveable pulleys is to have them perpendicularly disposed.

Here there are three of each kind, set in separate frames, technically known as *blocks;* to the moveable block the weight is hung, and is communicated as before to the three pulleys in each block by one continued cord. They are of various sizes, to keep the folds of the cord clear of each other, but this does not affect the principle of the subdivision of effort among the ropes. These determine the relation of the power to the weight—as they are increased, the power may be diminished, and *vice versa.* Here the number of ropes sustaining the weight are six; and, therefore, the weight may be six times as great as the power. This is clear, since it is evident that each rope sustains an equal part of the weight, which may, therefore, be considered as divided into six equal parts, and each part sustained by one rope.




There are many other combinations used; but the explanation of them all depends upon the same general principle, and the results may easily be verified by experiment, allowance being made for the weights of the pulleys themselves.—(See Plate I. Mechanical Movements.)

Perhaps the most elegant combination of pulleys and rope is the common "blocks and tackle." In this, the pulleys in each block are set side by side on the same axle, instead of being on distinct axles, as shown in the preceding figures. The rule of calculation is the same for all the three last varieties of combination; and may be shortly stated thus:—*Divide the weight by double the number of pulleys in the lower block; the quotient is the power required to balance the weight.*



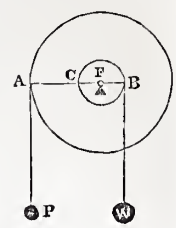

The pulley is of essential service in every situation where heavy weights are to be raised to a considerable height. On board ships it is, excepting the wheel and axle in the capstan, universally employed for that purpose. It is likewise made use of in cranes, when the advantage is wanted to be increased beyond what is had by the combination of wheels and pinions used. A considerable deduction, however, must be made in all cases for the effects of the rigidity of the rope, and the friction of the parts in motion. It may indeed, be here observed that, in the mechanical powers, in general, one-third of the calculated power is considered to be neutralized by these influences.

## CHAPTER III.

### THE WHEEL AND AXLE.

In the preceding chapter, the conditions of the action of simple pulleys, and certain combinations of them, have been examined, and it has been shown that they are referrible ultimately to the same principles as those on which the lever operates; in fact, that they are just more extended applications of that element. The *wheel and axle,* in like manner, is an extended applieation of the pulley, and in the simplest idea of it, it may be described as two pulleys of different diameters, fixed together, and having the same centre, of which the larger is the wheel, and the smaller, the axle. In this it is obvious, that a certain force applied at the rim of the larger, will balance some greater force at the rim of the smaller one, in which fact consists the advantage of the machine.

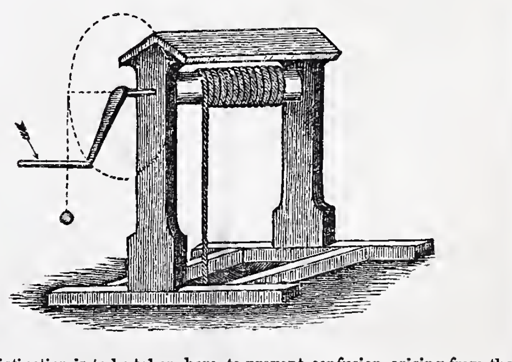
In the annexed figure, suppose A B, and C B, to be two pulleys of three feet and one foot diameter respectively, fixed together, and hung on the same centre F, and suppose a weight W, suspended at the circumference of the small pulley C B, and a weight P, at that of the large one A B; then draw the line A F B, horizontally across the centre; the cords by which P and W are suspended will just leave the pulleys at the points A, B, so that the weight P, acts at the distance A F, from the centre, and W, at the distance B F. It is, moreover, easy to see, that though the lines A F, and B F, be lying in *different* planes, the mutual effect of the forces P and W acting through them is just the same as if A F, and B F, lay in the *same* pulley; so that the line A F B, is to all purposes a lever sustained on the fulcrum F, and the same conditions of equilibrium apply to the machine. If, therefore, the weights P and W, balance each other on the pulleys, the products had by multiplying these weights by their distances respectively from the centre F, must be equal. Consequently, if W be 90 lbs., and B F, 6 inches, then $90 \times 6 = 540$, is the moment of the weight; and by the rule for levers already stated, (page 359,) we require only to divide 540 by the distance A F to ascertain the power P. The wheel being three feet, A F is eighteen inches, and $540 \div 18 = 30$, so that a power of 30 lbs., acting at A, is sufficient to balance 90 lbs. acting at B.




The power bears the same proportion to the weight, that the distance of the weight from the centre has to the distance of the power from the same point; or, as it is more shortly expressed, the power and the weight are to each other, inversely, as their distances from the centre, which is, indeed, another expression of the law of equality of moments, as applied to the lever.

Now, though the practical use of this machine is the same as that of the other combinations of pulleys—namely, to move weight or resistance of any kind through considerable space; yet the ropes are differently arranged; for, whereas in the former cases they do not terminate in the pulleys, in this case they do so. There must therefore be provision on each pulley for a length of rope, sufficient for the purpose of being coiled round it, which is simply attained by making the pulley of a proper depth. In regard to the wheel—as the power is usually applied by other means, the rope is dispensed with, and, in place of the wheel, one or more levers are employed, or in some cases, a toothed wheel and pinion.

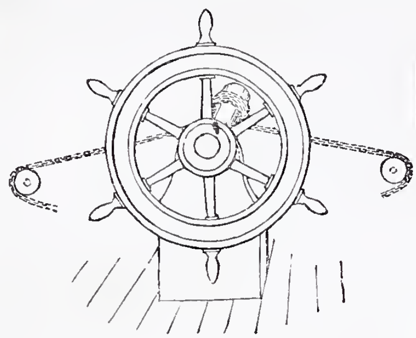
A simple and common application of the wheel and axle is made at the mouths of draw-wells, for raising the water in buckets. In the annexed sketch, the "axle,"* or more pro



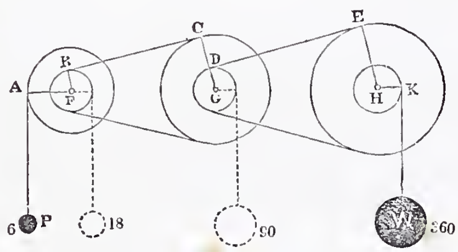
* A distinction is to be taken here, to prevent confusion arising from the antiquated term "wheel and axle." This name was doubtless inferred from the construction of the machine, which originally must have been a *bona fide* wheel and a *bona fide* axle, the latter being thick enough to act as a roller, on which the rope was coiled. In the present state of machines, the "axle," in fact, is not the axle, but is properly the barrel or roller on which the rope is coiled, and which is fixed upon the real axle. The name is retained here, as it expresses as well as any other the idea intended.

perly, the barrel is supported between two checks, and round it the rope is coiled, at the end of which a bucket of water hangs, which is the weight to be raised. On the extremity of the axle a cranked handle is fixed, which, when in motion, describes a circle, and this represents the "wheel," the force being applied as indicated by the arrow.

The capstan is another example of the wheel and axle. The axle is fixed vertically or horizontally, as it may be convenient, and in it a series of sockets are formed to receive the ends of bars to which manual power is applied generally, to raise the anchors of a ship, or to move forward the ship itself. The mechanism employed to manage the helm of a ship is a true wheel and axle. In this case, the arms of the wheel are projected through the rim, forming handles, by which the wheel is turned. The chain is wrapped a number of times round the axle, and led off on both sides round pulleys, to a lever upon the helm, to which it is attached. The steersman, by laying hold of the handles, turns the wheel, and thereby winds the chain up upon the axle on one side, and unwinds it on the other, so that the helm may be turned to any position, by managing the wheel one way or other.



Sometimes the axle of one wheel is made to act upon the rim of a second wheel, and the axle of this upon the rim of a third wheel. In such combinations, pulleys and belts, or toothed wheels, may be used. In the figure, for example,



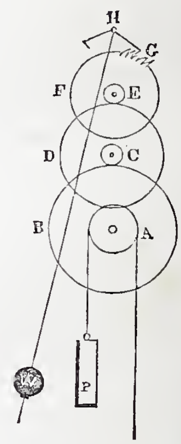

the power P, is applied at A, the circumference of the first wheel, and is so far concentrated at the axle B, from which it is transmitted to the rim C, of the next wheel. The force is in the same way transmitted, still more concentrated by the axle D to the rim E of the next wheel, at the axle K, of which the weight W acts. Now, to estimate the whole effect of these successive concentrations, it is to be borne in mind, that the belts B C and D E simply transmit, they do not concentrate, the force. Therefore, the advantage is to be found in the proportions of the diameters of the small pulleys or "axles," to the diameters of the corresponding wheels. The force of P at A is to the force acting along B C, as B F, to F A. The force at C is to the force along D E, as D G, to C G; and lastly, the force at E is to the force at K—namely, the weight W, as H K, to H E. Let the force P, be 6 lbs., and the wheels A, C, E, respectively 18, 25, and 32 inches diameter, and the small pulleys, 6, 5, and 8 inches, respectively; the advantage by the first wheel and axle is as 1 to 3, since 6 is contained in 18 three times; so that the force along B C is 18 lbs—by the second, it is as 1 to 5, so that the force acting along D E, is 5 times that at C, or 15 times the force at A; thus $5 \times 18 = 90$ lbs. Further, this force is concentrated at the third axle in the proportion of the diameters, or as 1 to four, which is sixty times the force at A, or 4 times that at E, being $4 \times 90 = 360$ lbs. for the ultimate weight W. Now, in this process, we have multiplied the several proportions together to ascertain the final proportion,—1 to 3, 1 to 5, and 1 to 4, being the proportions of each axle to its wheel, multiplied together, give 1 to 60, for the proportion of the power to the weight. But, instead of these figures, the diameters themselves may be used in expressing their proportions, and by multiplying them together, the same result will be had. Thus—

| | | | | |
|---|---|---|---|---|
| 6 to | 18, or | 1 | to | 3 |
| 5 to | 25, or | 1 | to | 5 |
| 8 to | 32, or | 1 | to | 4 |
| 240 | 14400 | or 1 | to | 60 |

Here $6 \times 5 \times 8 = 240$, and $18 \times 25 \times 32 = 14400$; and 240 and 14400 are still in the proportion of 1 to 60. Hence, a simple rule for finding the proportion of the power and the weight in a combination of wheels and axles:—Multiply the diameters of the axles together, and also the diameters of the wheels; the proportion of the products is that of the power and the weight.

A familiar instance of the combination of two wheels and axles is the common spinning-wheel, of which the object is to communicate a very rapid motion to a small spindle, by turning a larger wheel, over both of which a strap or band passes. The motion is given in the first place, by the hand to the spokes of the wheel, somewhere within the rim, describing a circle which is relatively the "axle" of the wheel; this again drives the pulley which is fixed upon the spindle, and its bobbin; that is a second wheel and axle. In this case, however, we have an example of the common purpose of the wheel and axle being reversed; for whereas the usual object is to concentrate power, the object in this instance is to convert power into rapid motion.

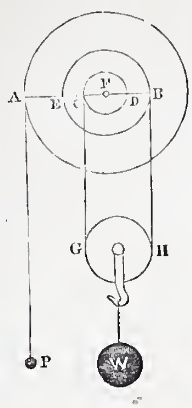
Wheels and axles constructed and connected by toothed gear instead of bands, are calculated on the same principle; instead of their diameters, the numbers of teeth are sometimes employed. In clock and watch work, there are many examples of combined wheels and axles. In some of these cases too, the direction of the force is reversed, the intention being to produce a quick motion by a heavy weight, or a spring moving slowly. In the annexed sketch, which represents the first train of wheels in an ordinary clock, P is the original force acting on the ratchet wheel A, on the axis of which is the wheel B, turning the pinion or lantern e, on the axis of D; this turns E, on the axis of the escapement wheel F, which again impels the pendulum or *weight* W by the pallets G, on the axis H. As the pallets and pendulum are virtually a wheel and axle, there are four wheels and axles here in train, and the functions of the power and the resistance are so far reversed.




The common crab-winch is an example of two wheels and and axles combined. The barrel and the wheel are on the same shaft; the former receives the rope round it, which is sustaining the resistance. A pinion on the upper shaft works into the wheel, and on the same shaft two cranked handles are fixed for the application of the power. Cranes are constructed upon the same principle, but generally more complicated. Machines of this description are intended to raise very large masses to considerable heights; and their power may be increased by the addition of block and tackle, affording in this way an instance of the combination of different mechanical elements for the purpose of concentrating force.

It is evident that if the strength of materials were unlim-

ited, and the conveniency of applying power, the same in all cases, we might increase the power of the single wheel and axle to any extent by increasing the diameter of the wheel, or diminishing that of the axle. Directly, however, this is impracticable; but the following simple contrivance obviates the difficulty by causing the weight to act on *both* sides of the centre of motion, and so that the one half of it almost balances the other half, leaving only a small portion of it to be balanced by the power applied. Let the outer circle represent the wheel, the power P acting at the circumference at A, and C D, B E, cross sections of two rollers of unequal diameters on the same centre F. Then the weight W hangs by the pulley G H, round which the rope passes, the two ends being coiled round the two bars, opposite ways, and so that the rope depends from the smaller at C, on the same side with the power, and from the larger, of course, on the other side at B. It is obvious, in the first place, that each of the ropes C G, B H, bears half the weight, and their distances from the centre are C F, B F, respectively. The more nearly equal, therefore, the rollers are in diameter, the less will be the difference of these distances; and therefore also the less will be the power required to make the equilibrium. In this way a very small power may balance a very large weight. But, more particularly, the moment of the force at B is half W multiplied by B F, and the moment of the force at C is half W multiplied by C F, or by D F, as D F = C F. The moments being opposed to one another, their difference is the product of half W multiplied by the difference of B F and D F, that is B D. As this is an unbalanced quantity, that there may be an equilibrium, there must be an equal moment on the other side, produced by the power P, applied at A. And in that case, P multiplied by A F, must equal half W multiplied by B D; or P is in the same proportion to *half* W, that B D is to A F; and therefore P is to W in the same proportion that B D is to twice A F, or the diameter of the wheel.

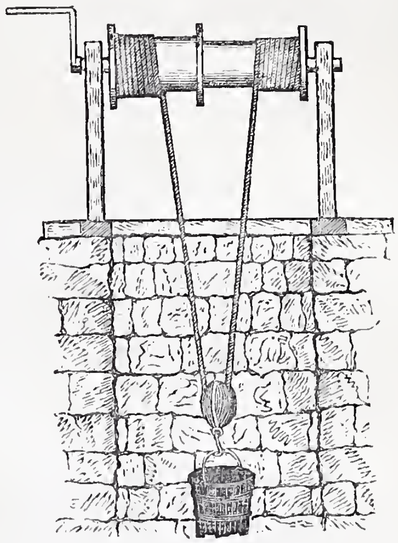



For example, suppose F B were twelve inches, F C eight inches, F A twenty-four inches, and the weight of W and the pulley G H, 900 lb., and therefore the weight on each string 450 lbs. Then, on the principles of the lever, the moment of B, on the side F B, is $450 \times 12 = 5400$; and the moment of C, on the other side F C, is $450 \times 8 = 3600$; and the difference of these moments, to be counteracted by the force at E, is 1800.

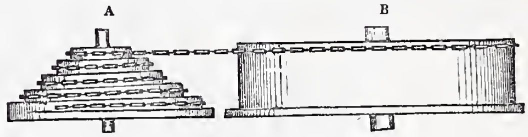
Therefore the *weight* in pounds, necessary to be applied at A, F A being 24 inches, is 1800 divided by 24, or 75 lbs. In this case, the weight sustained, that is 900 lbs., is 24 times as great as the power employed to balance it. This is plainly correct, for P : W : : B D : 2 A F, that is 75 : 900 : : 4 : 48.

It is on the principle now explained, that the Chinese wheel and axle is constructed for draw-wells, as in the figure. Here it is easy to see that a much greater length of rope is requisite in this machine to raise a weight through the same height, than in the common windlass. For, while a length of rope equal to the circumference of the larger barrel is wound up during one revolution of the axis, the weight is raised through a height just equal to the difference of the circumference of the two barrels; for the smaller barrel also unwinds one coil of rope. Consequently there will be as much more rope in this machine in proportion to the ordinary quantity, as the circumference of the larger barrel is greater than the *difference* of the circumferences; in fact, there must be rope additional sufficient to supply the uncoiling of the smaller barrel in the process of raising the weight.

If the resistance to be overcome be constantly the same, and to be overcome, however, by a variable force, it is evident that in order to overcome the resistance with equal effect at all times, the power must act at different distances from the axis; or, more precisely, the distance from the



centre must increase or diminish exactly as the power diminishes or increases, the *moment* of the power being thus always the same. If the power vary uniformly, a barrel of a conical form must be provided. This adaptation is adopted in the construction of the watch to suit the variable elasticity of the spring, the source of the power, as it evolves. The spring is enclosed in a cylinder, to the circumference of which one end is fixed, and the other end to the axle. When the spring is wound up to the starting-point, its elastic force is greatest; and it lessens regularly as the coil unwinds. To employ this




force equally, therefore, the chain is wound upon a conical wheel A, termed a fusee, at the smallest radius of which it acts in the commencement of the motion, as here sketched, its extremity at that end being fixed to the cylinder B outside. As the spring uncoils, it carries the chain off the fusee on to the cylinder, and is at the same time acting on the former at a gradually increasing distance from the centre, in the same proportion as its force decreases. Thus the moment of the elastic force of the spring is made to continue the same, and it therefore communicates a uniform velocity to the hands of the watch.

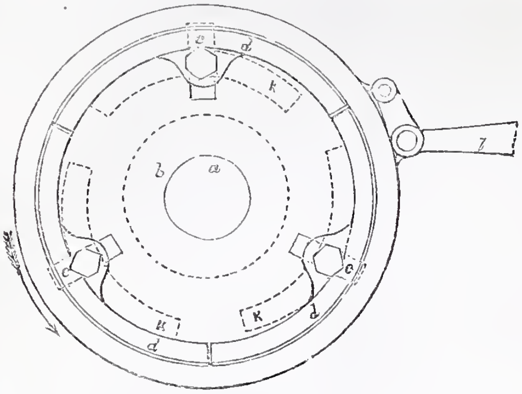
In all wheel and axle constructions in which the effect is produced by a rope winding on a barrel, it is evident that when the rope has coiled round the whole length of the barrel, as it returns over itself, it will act at an increased distance from the centre by the thickness of itself. This is therefore another source of variation, and accounts for the increased difficulty of raising weights the higher they are raised.

Finally, in practical calculations about the force of the ropes, &c., as media of power, winding round a centre, their true distance from that centre must be measured from the centre of the rope. For instance, in a rope of two inches diameter turning on a barrel twelve inches diameter, the true distance from the centre is half the barrel and half the rope, or seven inches, and, when it is coiled over itself, on the same barrel, its distance will be two inches more, or nine inches.

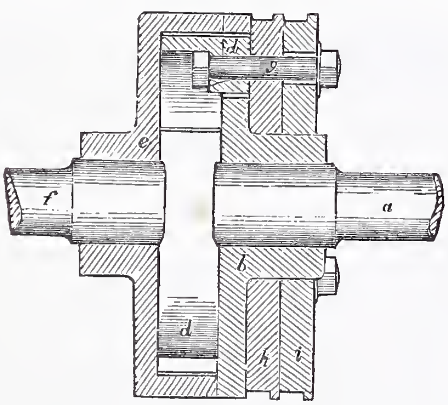
In our next chapter we shall turn our attention to the second class of mechanical elements.

## NEW FRICTION COUPLING.

The accompanying figures represent an end elevation, and a longitudinal section of a friction coupling, designed with the intention of combining, as far as possible, the essential requisites in machines of this sort—compactness, simplicity of construction, and durability.



In the figures, *a* is supposed to be the driving shaft, and *f* the one to which it is intended to communicate motion; *b* is a cast-iron disc, provided with a long boss, and keyed on the end of the shaft *a*. This disc has three radial slots *c*, disposed at equal distances near its outer edge, in which projecting pieces from the segments *d* are fitted to slide; *d*, *d*, are segmental pieces of metal, covered on their outer edge with sheet copper, and curved to fit the interior of the ledge of the disc *e*, which is keyed on the driven shaft *f*; *h* and *i* are two loose rings upon the boss of the disc *b*, the inner one of which, *h*, is provided with three spiral slots, *k*, placed at equidistant points, near its circumference. The outer ring carries three radial slots similar to, but shorter than, those in the first. Both of these rings are fitted with copper friction-bands, and levers *b*. *g* are bolts passing through the projections in the segments *d*, and also through the slots in the disc *b*, and the rings *h*, *i*, at the back of which last they are loosely secured by nuts.



If we suppose now that the shaft *a* is revolving in the direction indicated by the arrow, the shaft *f* with its disc being stationary, all that is necessary to put the latter in motion, is to tighten the copper friction-band upon the ring *h*, by means of the lever *b*. The friction generated by the band will gradually stop, or at least diminish, the speed of the ring, and as the shaft *a* with its bolts *g* is still moving forward, it follows that the segments will be gradually pressed outwards by means of the spiral grooves, and will of course come in contact with the interior ledge of the disc *e* on the shaft to be driven. The friction-band must be held sufficiently long to enable the bolts to get a hold upon the spiral grooves in the disc *h*, when they may be released. To stop the shaft *f*, all that is necessary is to tighten the friction-band of the ring *i*, and as the bolts are still revolving in a forward direction, the diminution of motion in the ring will cause the bolts, and consequently the friction segments, to contract or approach the centre of the shaft, and thus release them from contact with the driven disc. The force necessary to be applied to stop the machine is simply equal to the surplus friction of the segments *d* upon the base of the disc *e*.

## THE VOLTAIC BATTERY DISSECTED.

### CHAPTER II.

#### POSITIVE AND NEGATIVE METALS.

The preservation of the *metallic* portion of the voltaic combination in perfect working order, fully equals in importance the employment of a perfect and lasting diaphragm, and yet it is extraordinary how very much this principle is neglected in practice. We have visited many laboratories at home and abroad, and have observed with no little astonishment, the very unscientific condition, as well as construction, of the most expensive voltaic apparatus. This is owing, in a great measure, to the conflicting opinions of men of science with respect to the form, proportions of metals, and nature of electrolytes, best fitted for adoption in the battery; in consequence of which, students, who, with the laudable desire of acquiring in the shortest possible time the largest stock of scientific knowledge, attend the lectures of different professors, find themselves in the very unenviable predicament of not knowing whom to believe, or where to find those fixed and established principles so requisite for the successful pursuit of their private investigations.

In the former section it has been our earnest endeavour to set before the readers of this journal such information respecting the porous partitions in general use, as should enable them to lay down a safe rule for their guidance in the application of such substances; and in furtherance of a similar design with regard to other parts of the battery, we shall now proceed to detail those means whereby the voltaic metals may be preserved in that state best fitted for the proper development of electrical effects, and also what metals may be most advantageously used, and in what proportions, with a view to economy and power.

The metals most generally employed in voltaic combinations are zinc and copper—less generally, zinc and silver, or zinc and platina. Of those metals, zinc being that intended to produce or encourage the play of chemical affinities, it naturally becomes of the highest importance to use metal of such a quality as shall prevent any action but that which is auxiliary to the greatest development of electric energy. Now, it is well known, that the zinc of commerce is very impure, generally containing iron, lead, arsenic, or some one or more of these or other metals in varying proportions; but this is the zinc most frequently used in the voltaic battery. The consequence of course is, that thousands of voltaic circles are formed upon the surface of the metal, owing to the *different* electrical states of the *different* metallic particles; and, by their *local action*, not only *uselessly* destroy a *large quantity* of the positive metal, but counteract the development in the circuit of the full quantity of electricity which is set free by the *simple* union of the zincous atoms with the negative gaseous elements of the electrolyte. Furthermore, this local action causes the formation upon the zinc surface, of a variety of compounds which screen or defend that surface from the action of the electrolyte, and therefore either annul or diminish the affinity which would otherwise obtain between particles in opposite electrical conditions. Again, the acid in the fluid in connexion with the zinc, being attracted with *different* degrees of force by the *different* oxydes or chlorides formed on its surface, will not unite simultaneously with all, but only with that for which the affinity is strongest; therefore, in proportion to the number of foreign substances contained in the positive metal, so is the obstruction to the removal of those superficial formations which interfere with effective electrical action. It follows from these facts, that in the construction and employment of voltaic arrangements, the purest obtainable metal should be used; and, with this view, the Liege or Musselman's zinc is recommended, not as perfectly pure, but as the purest of the zincs of commerce.

It has been the fashion to employ *cast* zinc in some voltaic arrangements, particularly in Daniell's constant battery, in which, from the central position of the positive metal, it appeared advantageous; but such a custom is founded upon the grossest ignorance of the differences in the electrical conditions of metals subjected to different metallurgic treatment. Now it so happens, that *cast* zinc is *negative* to *rolled* zinc; and, therefore, it is clear that electric action *cannot* be as powerful where the former is substituted for the latter. For the same reason, *cast* zinc is acted upon by acid solutions with greater difficulty than *rolled* zinc; this, however, is *no* recommendation on the score of economy, —if we are to rely on Faraday's statement, that the electricity

developed in a voltaic circle is in proportion to the quantity of the positive metals consumed by *direct*, not *local* action. On such grounds, therefore, zinc in its *rolled* state, is in the best condition for employment in voltaic arrangements.

But, with the design of preventing local action, and of inc reasing the positive electrical condition of the zinc, amalgamation of the surface has been strongly recommended; and Sir H. Davy is adduced as authority for the fact, that amalgamated zinc is positive to plain zinc. Sir H. Davy did certainly make such a statement,—and it is correct; but Sir H. Davy did *not* assert that amalgamated *cast* zinc was equally positive as amalgamated *rolled* zinc; neither did he ascertain in what condition amalgamated zinc happened to be *after a few minutes' voltaic action;* neither has any of the many writers and experimenters of the present day seen fit to elucidate the subject; in consequence of which batteries are daily fitted up with *amalgamated* zinc, and batteries daily fail in *sustaining* the power developed on their *first* employment. Now we beg to inform those who are sufficiently unprejudiced to listen to reason, that there is a very wide difference indeed, between the electric conditions of amalgamated *cast* and amalgamated *rolled* zinc—the latter being far more positive than the former; and that with respect to both, the improvement which appears to obtain in their + condition in the first instance, rapidly diminishes after a short period—one good reason for which appears to be, that inasmuch as no description of commercial zinc possesses a perfectly smooth surface, the metal is never *equally* or perfectly coated in the process of amalgamation, many points on its surface become therefore soon exposed, and as a necessary consequence, numerous *zinc-mercury* circles are formed on the surface, the local action of every one of which tends to diminish the general action of the *zinc-copper* or *zinc-platina* circuit. Therefore, as the exposed points *increase*, so must the voltaic energy of the battery *decrease*, and this in an accelerated ratio. It is apparent, then, that the slight advantage obtained by the use of amalgamated zinc in the *first* instance, only leads to serious disappointment in protracted experiments; and influences the results to such an extent, as to furnish one good cause for those astonishing discrepancies which appear in the reported experiments of different investigators upon similar subjects.

It follows therefore from these considerations, that the simplest form of battery is decidedly the best for *all* purposes of experiment; and that if increased power is required, it will be much better to *add* to the series than resort to amalgamation, which is not only an expensive, but a troublesome, and as we have already stated, an uncertain process.

In the development of the electrical energy of the battery, much depends upon the nature of the fluids or electrolytes employed, with special reference to the superficial action on the positive metal, as well as to the preservation of the metallic surface in the state best suited for proper electrical development. For instance, acid solutions exercise a much more powerful chemical effect than alkaline, or saline; but it is *not* to be supposed from this that an acid solution will produce in a given time, a greater quantity of electricity than either of the others—certain necessary conditions in regard to the latter being observed, the detail of which however we shall reserve for our section on electrolytes. Suffice it here to say, that where acid solutions are used, there is much waste of zinc, unless where it is absolutely pure, which is never the case; for local action is encouraged by acid action, and thus not only is the positive metal unnecessarily consumed, but the compounds formed greatly reduce the conductibility of the solution. It will thus be found, that in a constant battery excited by an acidulated solution, the energy, though apparently, and perhaps really, intense at first, subsides considerably after the first five or ten minutes. It is thus that the battery, which in the *lecture room* produces the most brilliant effects, will be found in the laboratory of the experimenter to fail most signally in the protracted developments that were expected. To those, therefore, who desire to preserve in the combination an undiminished power, we unhesitatingly recommend the use of a solution of chlorhydrate of ammonia (sal-ammoniac) in connexion with the zinc; for we have found, after long use and much investigation, that with great development of power the waste of zinc is almost entirely prevented, and the metallic surface preserved in the condition best adapted for the due exercise of electrical influences. Another advantage gained by the use of this solution is, that inasmuch as its conducting power does not become impaired for a long period, it does not require frequent renewal, as is the case with acidulated solutions.

It is further to be observed, that in compound batteries it is of importance to cut all the zinc plates out of the *same* sheet of rolled zinc; for upon comparing plates obtained from different sheets, it has been uniformly found that one plate is positive to the other. One plate, therefore, in a *lower* electrical condition than the others, will govern the rest by reducing them to its own standard, and thus diminish the power of the battery. Even in cleaning the plates, which should be always done before use, they should be *all* dipped in the *same* acidulated solution; for if not, those plates which have been washed in the stronger solution, will be found to be in a *different* electrical condition to the others, and therefore will influence the general action. In order to clean the plates properly, they should be immersed in soft water, acidulated slightly with sulphuric acid, for about one minute, and well rubbed with a brush during that time, and afterwards dipped in water alone, then dried, and finally rubbed with emery paper; the same process may be adopted with the negative metal. These instructions may appear unnecessarily minute; but we assure those interested in the success of voltaic experiments, or of the volta-plastic art, that want of attention to the observations and instructions laid before them in these papers, will unquestionably lead to much disappointment, expense, and trouble.

In the next chapter it is intended to continue the subject of this paper, and to discuss the nature and advantages of the various electrolytes employed in voltaic combinations.

## HISTORY.

### CHAPTER VIII.

#### FOURTH ERA OF ROMAN HISTORY.

The fourth era of the annals of Rome—the mino of real history unmixed with mythological or traditionary legends—is the most important of all.

This period extends from about the commencement of the first Punic war, in the year of the city 490, till the date of the admission of the Italians to the full citizenship of Rome. At the close of the preceding era, it will be remembered, Rome was sovereign of Italy south of the Po. Rome—a state with elective magistrates, with magistrates elected for short statutory periods by the free citizens—was the sovereign of the other Italian states. These states, retaining more or less of their original institutions in municipal or local matters, were governed in all that concerned the affairs of the general state by the magistrates of Rome. They had no voice, no control, over the general government. The citizens of these states were personally free—the bond and brand of slavery were not upon them—but they had no civil rights, no civil privileges. They were, in their political capacity, on a footing with the subjects of a despotic monarchy. They were worse off. For though oligarchy is calculated to produce more talented and energetic rulers than a despotism; it produces, at the same time, more oppressive rulers to all who do not belong to the privileged or governing class. These are, by inclination, favourable to those with whom they have associated intimately since the dawn of consciousness, and can only retain power by acting in the interests of those who can bestow, or can withdraw, that power. Partly in ignorance of the feelings and interests of the non-privileged class, and partly in wanton sacrifice of them, they rule not for the good of all but for the gratification of their few co-mates in privilege. All aristocracies are, therefore, from the necessity of their nature, tyrannical. The Romans were, from their peculiar national character, eminently so. In the preceding chapters, I have traced their social history from the first dim dawn of their annals down to the 490th year of their city. We found them at first worshippers of those powers of nature which seemed to them elementary—worshippers of them *as* powers—as powers which could injure or could benefit, but were animated by no steady enduring benevolence, controlled by no sense of equity or justice. This rude theology remained unaltered down to the commencement of the fourth era—the savage ferocity of the old rites of worship remained unhumanized for a much longer period. The Romans had commenced their career as a warrior race, and

this character had been confirmed by circumstances. Every illustrative anecdote of their history shows that in them the more rugged virtues preponderated over the more humane. Honour is the prevailing sentiment in the tale of Lucretia—honour is the prevailing sentiment in the tale of Virginia—honour is the prevailing sentiment in the tale of Coriolanus—honour is the prevailing sentiment in the tale of the mother of the Gracchi. Sometimes it is a true, and sometimes it is a false, honour; but the feature uniformly held up for imitation and emulation is the power of controlling and silencing, the most powerful inclinations of nature to preserve a dignity of deportment—the immolation of the heart at the altar of external appearances. There is terrific power in the Roman character, little that is amiable. With the Romans virtue and bravery were designated by the same word. This practical stoicism is the groundwork of all high moral character in man; but, unmingled with other qualities, it is apt to degenerate into Pharisaical arrogance and oppression. In the Romans it was not merely unmingled with softening and refining attributes—it was perverted by an overruling passion for acquisition. This character, as I had formerly occasion to observe, was fully developed in the city—the seat of power—among a people divided into only two classes—the intriguing and ambitious few, the rude and idle many, between whom the spoils of every conquered state fell to be divided. All aristocracies are inevitably tyrannical, but the sceptre of Rome was literally a rod of iron. Rome's despotism, exercised on all its subjects alike, was exercised upon people of very varying characters. The Greeks, in the south of Italy, ennervate, and effeminate, gave little trouble; but the Latin, Ascan, and Etruscan tribes, educated in the same school as the Romans themselves, had much of their proud and unbending character. They were not naturally inclined to acquiesce in a state of political vassalage; and thus predisposed, the exactions of the Romans furnished them incessantly with valid causes of discontent.

These were the sources of those internal struggles which tasked the energies and filled the thoughts of the men of Italy, from the 490th to the 665th year of the city of Rome. They worked out their issues under the modifying influence of the external relations of Italy during that period, of which it will therefore be necessary to premise a brief outline.

The first state with which Rome came into serious collision, after subjecting the whole of Italy, was Carthage. I have already had occasion to mention the treaty contracted between these two states so early as the 245th year of the former city. From its terms alone some faint idea may be formed of the power and ambition of Carthage even at that early period. The Carthaginian state resembled Rome in this, that over its wide extent the sovereign sway was exercised by the elective magistrates of one city. Carthage was originally a colony from Tyre—a city inhabited by a Semitic race, which we know from the "Book of Kings," to have stood at one time in intimate relations with the Hebrew monarchy, and the language and letters of which, as far as we can judge by the imperfect monuments that have come down, to approach even more closely than those of any other Semitic tribe to the Hebrew. Carthage, at the time we treat of, long before was a perfectly independent state. Natural predilections had more than once made her fleets hasten to the assistance of Tyre in the extremities of that state; and so long as Tyre survived, some annual observance of religious rites kept up an intercourse between the two communities; but Carthage was, and had long been, an independent self-governing state. It is a curious coincidence that the union of several independent settlements, within the precincts of one city wall, to which I incline to attribute much of the vitality and elasticity of the Roman constitution, occurred also in the construction of the Carthaginian. Carthage stood about the 10th degree of eastern longitude, measuring from Greenwich, and the 31st of northern latitude. The ground, from which even its ruins have mouldered away, is an expanse nearly square, bounded to the north and east by the sea, to the south by the lake of Tunis, and to the west by a broken desert country. Two isolated eminences within this space were occupied by two settlements; the one termed Magor or Magalia, the other Byrsa. Both claimed to have been Phœnician settlements; but while the claim is corroborated in the case of the latter, by the name *Byrsa*, which seems to be the same with the Phenician *Bosra*, a fort; the designation of the former seems to be the appellation used by the indigenous Libyans to designate a collection of dwellings. A third settlement, posterior in date to any of the others, was known by the name Katum or Cothen, indicating a cut or excavation, and seems to have been the harbour. All these were included within the walls of Carthage—all these continued till the final devastation of the city separate territories with exclusive fortifications, and seemingly with exclusive jurisdictions. The annals of Carthage are unfortunately too fragmentary to permit of our pursuing this inquiry further, or founding any trustworthy theory upon the apparent coincidence. The executive, and apparently the judicial, authority was reposed at Carthage, in the hands of two magistrates elected, it does not very clearly appear by whom, or for what term, whose title is identical with that found among the early Jews, and rendered in our version of the Holy Scriptures by the word "Judges." Carthage had, like other early nations, recourse to the practice of colonization. Partly it may have been driven to this by the necessity of getting rid of a redundant population; but a more immediate object seems to have been to render these colonies subservient to the mercantile enterprise of Carthage, as those of Rome were to its thirst for extended territory. The earlier Carthaginian colonies extended south and east along the coast of Africa towards the Syrtis, where they were arrested, in their progress, by the Grecian and Egyptian power. They next stretched along the western coast of North Africa, at least as far as the straits of Gibraltar. The coasts of Spain had long been known as an advantageous site of traffic to the Phœnicians of Syria. The Carthaginians did not fail to settle colenies there also. And, during the course of the era of Rome, at which I have now arrived, they formed settlements in Sicily, and even for a short time in the islands of the Tyrrhene sea. All these colonies were kept in intimate relation with and dependence upon the parent state. They formed a chain of forts along a line of Mediterranean coast which hemmed, as with a semicircle, the domain of Italy. The natives of the lands, in which they were planted, were inveigled into alliances with Carthage; such alliances as a state advanced in civilization forms with tribes scarcely emerged, or not emerged, from barbarism—alliances like those, begun by the pilgrim fathers in Massachusetts, when they purchased miles and miles of rich land on the Connecticut River, for a few yards of wampum and a dozen blankets; the final ratification of which has just been carried into act by the government of the United States, in the forcible expatriation of the Creeks, and the butchery of the Seminoles. The Carthaginian garrisons, or colonies, were supported, and the alliance, or vassalage, of the native tribes secured, by armies composed partly of Carthaginian citizens, partly of the contingents of the subdued Lybian tribes in the immediate vicinity of the city, and partly of mercenary troops hired from the neighbouring independent sovereigns. The commercial pursuits of the Carthaginians furnished them with a large and powerful navy, and with the means of keeping afoot huge armies. They were more advanced in civilization than the Romans—their luxury was the result of wealth—acquired by industry, it did not corrupt them so much. They had a literature of their own, and were not unacquainted with that of Greece. They were more wealthy than the Romans. But there were three sources of comparative weakness in the Carthaginian state which told in favour of the Romans. The Carthaginian nobility do not seem to have had the healthy element of a free plebeian *caste* to keep their nobles in check. The feuds among the nobles not being restrained by the necessity of making common cause against an encroaching power, indulged their hereditary feuds with a virulence that shook the state. Wanting a free plebeian *caste*, they had no materials for that tough infantry which formed the nucleus and strength of the Roman army. Again, the peculiar commerce they engaged in was of a nature to weaken the sense of honest pride. It was mainly conducted with savage tribes—the habits of veracity and fair-dealing contracted by their navigators and supercargoes, were akin to those learned in our day in the Bight of Benin. The fraudulent practices of the over-reachers of savages, and the violent practices of the dealer in slaves, combined to generate a half-huxter, half-pirate, character, which contaminated by its vicinity more or less all classes of the citizens. The less pliant Romans were so struck with this feature of the Carthaginians, that Punic faith passed with them into a proverb. The last of the three causes of Carthaginian weakness, to which I adverted, was the diffusion of its territory. The territory of the Romans was compact and centrical, and from it an attack could be directed

with ease against any point of the long surrounding line of Carthaginian coast. No point along this line was supported by any breadth of densely peopled country behind; and, once secured by an overmastering force, the result was something like the operation of breaking the line in naval warfare. The interruption between the extremities was broken up, and the Carthaginians were cut off in detail.

It is not necessary for my purpose to enter into a minute detail of the pretexts in which the various wars between Carthage and Rome originated, or the displays of individual heroism and genius to which these wars gave occasion. The theme is a tempting one, but I may not yield. It is sufficient for my present purpose, to say that each of these states having cleared away all rivals on the ground which each occupied, came into direct contact along by far the greater portion of their respective frontiers, about the commencement of the fourth era into which I have portioned the history of the Roman republic. The small, but fertile territories of Sicily, Sardinia, and Corsica, which intervened, served rather as incitements and as pretexts for quarrel, than as peace-preserving intervening objects. By the time the two powers came thus to stand face to face, each had acquired a full consciousness of its own power, and unbounded thirst for dominion. Neither could endure in its vicinity an independent and equally powerful state. The allegations on either side, at the commencements of wars, were mere specious pretexts. The preliminary "biting of the thumb"—and asking, "Is the law on our side, if I say aye?" The power and the ambition of the two states determined that there should be war, and that that war could only terminate with the final subjection of one of them, and its extermination as a people. Three wars, with short breathing times of peace, between Rome and Carthage, occupied from the 490th to the 590th year of the city. In the first, Rome acquired a naval force—a warlike marine, and knowledge of naval tactics. In the second, the Roman generals learned to apply those principles of war which experience had shown to be available in the partisan warfare of hills and valleys, and in the subduing of small states, the limits of which were the walls of cities, to the overthrow of extended empires. The military knowledge of Rome ceased to be a mere matter of discipline, and was advanced to the dignity of tactics. In the third, Carthage was destroyed, and the plough passed over her ruins. Rome inherited her ascendancy among the Celtic tribes of Spain; and, after half a century of interim arrangements, giving rise to constant battles, and short-lived local tyrannies—the greater portion of northern Africa was erected into a dependency of Rome.

During this protracted struggle with Carthage, the range of Rome's external policy was not limited to that state. While tracing the rise and progress of the school of Alexandria, I was obliged to advert to the history of eastern Europe, western Asia, and Egypt. This was by anticipation, for I have yet to go over that ground more in detail. I must, however, recall attention, briefly, to that anticipatory sketch. It will be remembered that the Persian monarchy, erected on the ruins of preceding dynasties, extended its sway over Asia Minor, Western Persia, Mesopotamia, Syria, and Egypt. All these countries were inhabited by tribes, retaining their original language, customs, religion, laws, and military organization. But they had no control over, or part in, their civil government. That was exercised by a hierarchy of satraps, appointed by, and dependent upon, the one possessor of the Persian throne. There was immense variety of social institutions within this empire, but for purposes of external aggression it could be made to move as one mass. This truth was repeatedly experienced by the Greeks. That people inhabited the continent between the gulf of Thessalonica and the Adriatic sea—the peninsula, now called the Morea, and the innumerable islands with which the eastern extremity of the Mediterranean is studded. Its colonies extended along all the shores of Asia Minor, Thrace, the coasts of the Black Sea, the south of Italy, Sicily, and the coasts of north Africa intervening between Egypt and the Carthaginian territories. These colonies were held to their parent states by a slenderer tie than the colonies of Rome or Carthage. No one of these parent states had attained to such an ascendency over the others, as Rome and Carthage in their respective spheres. A common language, common customs, the consciousness of relationship, kept up a kind of cohesion among the Greeks. They generally drew together when danger impended. But there was no permanent, all-embracing, organized, union among them. The development of the individual character was more prominent in Grecian states than the development of the social disposition: and this was the case also in the relations of these states with each other. The wars between the Persian empire and the Greek people, showed how much more important was the development of the free energies of the individual, than the mere conventional filling of individuals into certain places in society. Twice did the Persian monarchs hurl their organized masses against Greece, and twice had the spontaneous, unpremeditated, imperfect alliance of Grecian freemen power to shatter to atoms and drive back the hordes of slaves. Circumstances, to which I shall have to advert hereafter, united for a short time the whole power of central Greece in the hands of Alexander; and the brief career of that monarch was sufficient to overthrow the Persian dynasty. Immediately upon his death, the short-lived union of Greece was again broken up; but Greeks maintained, nevertheless, the sovereignty of Asia. Eastern Europe, western Asia, and Egypt, may be considered from the death of Alexander, until their conquest by the Romans, as the seat of Grecian power. There were myriads of people scattered over this space, but Greeks were their masters—Grecian rulers, Grecian arts, literature, and science, predominated everywhere. Western Asia was shared between the Greek principalities of Pergamus and Syria, but even the inner Bactria had its Greek sovereigns. Egypt was a Greek principality—so was Macedonia, including Epirus, Thessaly, and Greece, to the isthmus of Corinth. The Thebans and Athenians remained independent states. On the north side of the gulf of Corinth was a confederacy of free cities, named the Etolean league; on the south another, including in its palmy days, Corinth and Megara, called the Achæan league. Cyrene, between Carthage and Egypt, and most frequently subject to the latter, was a Greek state. The south of Italy, as we have repeatedly observed, was mainly peopled with Greeks, and so was Sicily. Even at the bottom of the gulf of Genoa there was a Greek city—Massila, now Marseilles.

Rome, as formerly observed, was for a moment brought into contact with a Grecian state beyond the limits of Italy, when the Tarentines called in the assistance of Pyrrhus. The attention of the civilized Greeks, however, had been directed to the energetic youth of Rome long before any Grecian state measured swords with it. Aristotle makes mention of its institutions as curious and interesting phenomena. The appearance of the Romans among the Greeks, as taking an active part in Grecian politics, was reserved for a later period. There is something about this first appearance. In 519, during the interval between the first and second Punic wars, the temple of Janus, at Rome, was shut, indicating that the republic was at peace with all the world—rather a rare occurrence in its quarrelsome annals. By this time the Illyrians had become rather a considerable nation. Having convenient harbours and retreats for shipping, they carried on a piratical war against all their neighbours; and it thus happened that they came to commit depredations upon some Italian traders, the subjects of Rome, and therefore entitled to Roman protection. An application on the part of the Romans for redress, was answered on the part of the Illyrian queen, that the seas being open no one could answer for what was transacted there; and that it never was the custom of kings to debar their subjects from what they could seize upon by their valour. The Roman envoy, with characteristic pride, stated that his country was regulated by different maxims—that there the crimes of private persons were restrained by the authority of the state, and that Rome would find a way to reform the practices of kings in this particular. The queen was incensed, and viewing these words as an insult to herself, had the Roman deputy waylaid and murdered on his return. In revenge for this outrage, the Romans made war on the queen of Illyricum, obliged her to make reparation for the injuries she had done to the traders of Italy, to evacuate all the towns she had occupied on the coast, to restrain her subjects in the use of armed ships, and to forbid them to navigate the Ionian sea with more than two vessels in company. The Romans, being desirous of having their conduct in this matter approved of by the nations of that continent, sent a copy of this treaty, together with an exposition of the motives which had induced them to cross the Adriatic, to be read in the assembly of the Achæan league. They soon made a like communication at Athens and Corinth, where, in consideration of the signal service they had

performed against the Illyrians, then reputed the common enemy of civilized nations, they had an honorary place assigned them at the Isthmian games, and in this manner made their first appearance in the councils of Greece. The highly educated Greeks were struck with the energy of the Romans—the quality in which they felt themselves and their fellow-citizens to be most deficient. The simplicity of the Roman character they mistook for high moral excellence. The Romans, a plain uncultivated people, having a good cause by the hand, conducted it in a plain straightforward manner, and told a plain tale when they had done. They acted justly; for, having to do with notorious habitual thieves, thoy could scarcely make a mistake. They told their tale plainly, for, having no literature, and but a narrow range of ideas, they could not tell it otherwise. But the imaginative Greeks attributed high intellectual and moral excellence to this rude energy. They persuaded themselves that the Roman rusticity was, in reality, the result of philosophy. They did not wait to see whether the Romans could be equally just when it was against their interests—they did not wait to ascertain whether the same energy might not be available to plunder others, as to defend the property of its owners—they set up the Romans as idols, for Greece to worship; and, as is always the case, discovered in time that animated idols are more exorbitant than idols of wood, stone, or metal.

Having thus established a character in Greece, the Romans waited patiently for an opportunity to avail themselves of it. Towards the close of the second Punic war, Philip king of Macedonia sent auxiliaries to the Carthagenians. Some of these were taken prisoners at the battle of Zamia, and Philip sent to demand their liberation in rather arrogant terms. The quiet resolute answer of the Roman Senate was, that the king of Macedonia appeared to desire a war and should have it. Philip however had other business to settle, before he avenged himself of this taunt. He had got himself appointed head of the Achæan league, and was availing himself of the influence this situation gave him to make himself absolute master of Greece. In the prosecution of this scheme, he laid siege to Abydos in person, and despatched an army at the same time to besiege Athens. The Athenians—(this was one fruit of the good character the Romans had earned by the Illyrian transaction)—sent envoys to Rome to sue for protection. "It is no longer a question," said the consul Sulpicius, in his harangue to the people, "whether you will have a war with Philip, but whether you will have that war in Macedonia or in Italy. If you stay until Philip has taken Athens, as Hannibal took Saguntum, you may then see him arrive in Italy, not after a march of five months, and after the passage of tremendous mountains, but after a voyage of five days from his embarkation at Corinth." And by this argument the reluctant people were induced to engage in a new war before the old was well terminated. It lasted five years, and was terminated by the defeat of the Macedonian king. The Romans were not yet in safe condition, but their conduct at the close of the war if not adopted with a view to future conquest, was as well calculated to facilitate it as if it had been. The Romans obliged the king of Macedonia to withdraw his garrisons from every fortress in Greece, and to leave every Grecian city, whether of Europe or Asia, to the full enjoyment of its own laws. They obliged him to surrender all his ships of war but one galley. They made him reduce his ordinary military establishment to five hundred men, and forbade him entirely the use of elephants. For themselves, they desired only to have the Roman captives restored, deserters delivered up, and a sum of one thousand talents to reimburse the expense of the war. By this policy, the Romans at once humbled and weakened the Macedonian state; they left Greece split up as before, into a number of weak jealous republics; they increased the originally favourable estimate of their character by a show of disinterestedness; and they accustomed the Greeks to look up to them as protectors—that is, as superiors. To give the greater solemnity to the gift of liberty which they made the Grecian states, they had this act of munificence proclaimed at the isthmus of Corinth, in presence of multitudes met from every part of Greece to solemnize the ordinary games. Their flatterers or their dupes extolled them as the restorers of freedom to mankind—as if freedom were a thing which one could give and another receive—as if the mere acceptance of nominal freedom as a boon did not show that the capacity for it was dead within the soul. These idle ceremonies were performed in the year of the city 557.

As usual one war led to another. Antiochus, the Greek king of Syria, advanced to the assistance of the king of Macedonia when it was too late. The Roman deputies charged with the execution of the recent treaty, encountered Antiochus at Lysimachia, a city of Asia Minor. They remonstrated against some of his proceedings in that country as affecting the possessions of Philip. "The Romans," they said, "had not rescued the Greeks from Philip to deliver them over to Antiochus." That monarch replied with sufficient haughtiness; but his attention being called at the moment to Egypt, and that of the Romans to Spain, no immediate hostilities ensued. The Romans, however, continued to make the necessity for watching the motions of Antiochus a pretext for retaining hold of several Greek cities; and they availed themselves of the possession of these cities to take an active part in the politics of Peleponnesus. Hannibal, about this time an exile from his native land, took refuge at the court of Antiochus, a circumstance which augmented the jealous vigilance with which the Romans watched the motions of that monarch. The ultimate result was a war between Antiochus and Rome, in which the Grecian states took different sides. In the year of the city 562, a Roman army set foot for the first time in Asia. Still the Romans preserved the appearance of magnanimity. Upon the defeat of Antiochus, large territories were taken from his kingdom of Syria, but the greater part of them were shared between the Greek king of Pergamus, and the Greek republic of Rhodes. Some few of the Asiatic cities were restored to independence. The Romans contented themselves for their own share, with the reimbursement of their charges during the war, and the character of the liberators of the Asiatic as well as the European Greeks. Thus they at once gratified the ambition and cupidity of their citizens, multiplied and weakened the independent states in the countries where they exercised their arms, accustomed the nations to regard them as mirrors of justice, and familiarized men with the notion that the Romans had the right as well as the power to gift away kingdoms and provinces.

The time was now ripe for further steps of aggrandizement. A quarrel with the king of Macedonia, led to a war in which Illyricum was involved. It terminated favourably for the Romans who availed themselves of the opportunity to suppress these kingdoms, and organize the territories over which they had extended their sway into seven republics, in which government should be administered by councils and magistrates chosen by the people. These republics were nominally independent, but they were organized under the auspices of fifteen Roman commissioners appointed for an indefinite period, and in presence of a Roman army and general which was allowed to become permanently stationary. There were no materials for republican governments in the Macedonian provinces in which this form of polity had never existed. The consequence was a revolt, and attempt to re-establish the kingdom, which ended in the avowed erection of Macedonia into a dependent province. From before the subversion of the Macedonian kingdom the tone of the Romans towards the other Greek states, had been materially changed. Proud soldiers soon grew tired of aping humility and moderation. In consequence of this change, many citizens of Achaia took part with the Macedonian king, for which at the close of the war, they were cited to Rome. About a thousand were dispersed through different prisons in Italy; and of these, when set at liberty after a detention of seventeen years, only 300 survived. [The historian Polybius was of the number.] Such treatment was not calculated to assuage dissatisfaction; but Roman policy encouraged the mutual jealousies of the Grecian cities, and when at last they had recourse to arms, one after another, they fell an easy prey. Corinth, the wealthiest city in Greece, was plundered and sacked in the same year—some have said on the same day—as Carthage, in the 590th year of the city of Rome: and from that time, the republican states of central Greece ceased to be numbered among the nations.

It is not necessary, for the purpose of the present section, to trace further the transmarine conquests of Rome. To the close of this era, the limits of her dependencies remained nearly at the extent to which I have traced them, in following the progress of events. We have now a new element added to the Roman state. There is first the city of Rome—by the citizens of which, the magistrates are elected; within which, is the seat of the central executive government, the central judicature, and the great council of the nation, the senate. There is in the second place, the rest of Italy, a congeries of municipalities regulating their own

local affairs, the resources of this extensive country both in men and money, are available to the general government of Rome when engaged in war, but the mass of the inhabitants have no control over that government, be they willing or unwilling, be it for their interest or not, they must move as it determines they shall move. Lastly, there are the foreign dependencies in Spain, North Africa, and Greece. These pay tribute into the national coffers; but in return, they require standing armies to keep them in subjection. The Italian subjects of Rome are forced to furnish their contingents to these permanent drains upon their best and most vigorous population. The tribute goes to enrich the city of Rome alone—and after this fashion. Before the reduction of Macedonia, the Roman citizens had been treated as subjects, and permitted themselves to be taxed. They were required at every census to make a return of their effects upon oath, and besides other stated or occasional contributions to the public, paid a certain rate on the whole value of their property. But upon this event, they assumed more entirely the charactor of sovereigns; and having a treasury replenished with the spoils of other kingdoms, they entirely exempted themselves from their former burdens. In addition to the tribute of Macedonia came the tribute of Carthage, rents of Campania, and the tithes of Sicily and Sardinia. One consequence of this altered position, was a marked increase in the magnitude and splendour of their public works. Another, owing to the circumstance so often adverted to, that Rome, the seat of election to all civil offices, was inhabited almost exclusively by a few powerful and ambitious citizens, and by a mass of idle and venal citizens, was the diversion of large sums of public money to private purposes, and a great increase of luxury. These two results combined to produce a third: the sharpening of the Roman appetite, already sufficiently strong, for war and plunder.

Having thus traced the workings of the Roman government externally, and the reaction of the effects they produced among surrounding nations upon that government itself, I am now in a condition to trace and account for the peculiar development of the internal constitution of the government during this period. I had occasion at the close of last chapter to allude to elements of anarchy slumbering undeveloped in the Roman state at the close of the third era. There were in the first place, the unsettled disputes of tho Patricians and Plebeians; in the second place the inequality between the Roman citizens and the free citizens of the various Italian states, which had one after another been brought under the yoke of Rome. Whatever had been the fortunes of the Roman state, these elements must, assuming that the state remained entire, have worked out new revolutions in its social arrangements. The peculiar progress of events modified the form of these revolutions, but did not occasion as it could not check them.

The disadvantages under which the Plebeians laboured, led to those disquiets, in which the Gracchi successively took an active part. The objects of these great men have been much misunderstood. The Agrarian law for which they contended, is often thought to have been a law limiting the amount of landed property which each citizen was allowed to acquire; and much virtuous indignation has been expended on the folly of such an interference with honest industry and ambition. The Agrarian law of the Gracchi was nothing of the kind. I have mentioned formerly the practice of the Roman government to appropriate certain portions of the territory of conquered states, and to settle colonies upon it. In these colonies, a certain number of ploughgates was allotted to the Plebeian, and a certain number to the Patrician colonist. The Patricians, however, had availed themselves of their predominant share in the government to alter this first and tolerably equitable arrangement. Like the oligarchy in every country, they continued, even when the Plebeians wrung from their grasp a share in the executive, to soothe by their blandishments, or puzzle by a multiplicity of questions, the well-meaning democracy, and thus to make the new frame of government work on smoothly in the corrupt routine of the old. The Plebeians had got a consul of their own *caste*, but the government was as aristocratical in its tendencies and conduct as before. Among other abuses, the public lands in the various states of conquered Italy, instead of being parcelled out as the law ordained, in certain proportions to colonists, were gifted in large blocks to the most wealthy Patricians. Tiberius Gracchus, in his travels through Italy, saw that the effect of this illegal practice was to engross large tracts of land in the hands of a few nobles who rarely visited and stocked it with slaves. The surplus population of Rome, for which these lands were intended to form a drain, was growing up meanwhile in beggary and vice. The corruption at elections was teaching theseacklands to live upon alms. The increased frequency of the emancipation of slaves by Roman citizens was bringing a yet lower admixture into close and contagious contact with the demoralising Plebeians. Gracchus saw that this illegal destination of the public lands, was peopling Italy with slaves, debasing the Plebeian citizens, and converting the Patricians into Oriental satraps. He may have attributed this undeniable degeneracy, the result of many co-operating causes, too exclusively to the one which had everywhere struck his eyes in travelling over Italy. He may have attributed to the restoring of the old law, effects which it might have been found inadequate to produce. It is the quality of genius to attach undue importance to its favourite pursuits, and it is the enthusiastic perseverance, the result of this over-estimate, that enables it to effect good. Be these as they may, the cause of Gracchus was the cause of justice—at least as far as Roman citizens were concerned. It was no dreaming theory—it left enterprise and industry free—it sought to bring back their birthright to the poor and oppressed. This was a worthy cause for the only Roman on record, who, fully possessed of physical courage, shrunk revolted from the violent career of conquest and plunder, to struggle and to die in. He was vanquished, because the degraded *caste*, for the rights of which he stood up, shrunk from his side; because the Patricians, when they could not otherwise get rid of him, did not quail at murder. His place was taken by his brother, who was in like manner murdered; and thus were the powerful Patricians enabled to go on appropriating lands to which they had not the shadow of a right, and the electoral rabble of Rome left to become more and more degraded. "Her jewels," as the fond but noble-spirited mother of the Gracchi called her sons, were indeed jewels trampled under foot by those who knew not their value. But as every crime draws its own appropriate punishment along with it, so did the assassination of the Gracchi by the senate. This was the first step in blood. Sylla and Marius paid it back tenfold upon its perpetrators, nay the extermination of so many houses at Pharsalia can scarcely be regarded in any other light than as the necessary consequence and fitting punishment of the murder of the Gracchi.

The inequality between the Roman citizens and the other free Italians, first attracted discussion about the year of the city 627. It was discovered that the censors had been in the habit of surreptitiously entering non-electors on the rolls. It was found that a non-citizen had been thus clothed with consular dignity. This led to a proposal for the expunging of aliens; and this proposal in turn led to the natural inquiry, what better were the citizens of Rome than the other freemen of Italy? After some years of unavailing muttering and murmuring, Livius Drusus, proposed about the year of the city 660, that the Italian allies should be admitted in a body to rights of citizenship. The proposal was received with one peel of derision and execration from all classes of citizens. The inhabitants of Italy, enraged at such a contumelious reception of a claim upon which they laid much stress, began to form combinations. At Rome, inquiry was instituted to discover the abettors of the allies, and several persons favourable to their claim were sentenced to banishment. The news spread over Italy, and was immediately followed by a meeting at Corfinium of deputies from the majority of the Italian states to form a senate and elect consuls. Simultaneously, twelve of the bravest and most powerful states—some of Etruscan, some of Ascan lineage—took arms, and sent envoys to Rome to demand participation in all the privileges of Roman citizens, the value of which had been so materially increased by their assistance. A brief supercilious reply from the senate was followed by active hostilities on both sides. The social war, as it has been called, lasted for four years, and ended with the victory of the Romans. This victory, however, was purchased by conceding the right of citizens to all the Italian states that did not riso in arms, or were induced to abandon the league, before the close of the war. About the year of the city 670, all the free inhabitants of Italy from the Rubicon to the straits of Messina, were become Roman citizens. Italy was Rome.

The effects of this measure were not immediately perceptible to their full extent. The number of citizens on the rolls was not more than doubled; and as the elections could only take place at Rome, the name of citizen to all at a distance, was a

mere illusory title. As before, the elections continued to be managed by the wealthy intriguers and the venal votes of the capital. The latter class received, however, a dangerous addition to their numbers. It was only the slave of a Roman citizen who became a Roman citizen by emancipation; now however that the number of citizens was so much increased, the accession to the Plebeian ranks from this source became so great that a law was introduced to check it. All the needy and serviceable clients of the wealthy houses now became Roman citizens. The conduct of the Senate towards the Gracchi had sanctioned the removal of political enemies by violent means; and this extension of the qualification of citizen introduced multitudes into the comitia, always ready to do such service. Rome thus became more corrupt than ever, and the permanent inhabitants of Rome continued as before, the *de facto* masters of the state—the nominators of the temporary rulers.

The ground is now clear for a review of the Roman republic at its full growth—of its citizens and slaves—its literature, science, morals and religion—its laws and armies—in short, of the whole working of the machine from the year of the city 670, when its organization was completed, till the year 782, when it worked itself out.

## COAL FIELDS OF GREAT BRITAIN.

### CHAPTER IV.

#### MID-LOTHIAN COAL FIELD.—UPPER SERIES.

In the account we have furnished of the coal-fields of the valley of the Clyde, we have mentioned many facts regarding its strata, equally applicable to almost all coal-fields whatever. Some of these relate to the general structure of the strata, which usually consist of alternating layers of sandstone, massive and laminated; micaceous, sandy, and clay shales, of various colours, but chiefly gray, black, and bluish gray; fire-clay, with imbedded nodules of clay ironstone, or layers of ferruginous sandstone; ironstone in bands, fewer or more in number, and when intermixed with coaly matter, of the character of what is called black band. Ironstone, however, occurs most frequently in clay-shale strata, in thin bands or nodular layers. The colour is generally slate gray, but sometimes red. Black-band ironstone is black or fawn coloured, with streaks or riband-like stripes of coal, or coaly matter, alternating with thin layers of the ironstone. The coal occurs most frequently in rhomboids; when possessed of a splintery fracture, it is called splint-coal; when compact and in cubic masses, it is called cannel coal. Anthracite or blind coal is that variety which does not emit flame. The limestones are commonly of various shades of gray; and, when of marine origin, almost always appear as if, in a great measure, composed of minute encrinal or coralline remains, sometimes intermixed with shells. The beds of these minerals are of no determinate thickness or order, as to the mode of superposition, except, that coal may generally be said to over-lie a bed of fire-clay, containing exclusively the remains of the stigmaria ficoides, and that the roofs of coal almost, or frequently, consist of clay shale or faikes—a name generally applied to sandy carboniferous shales.

Such is a brief outline of the lithological nature of a coal-field in general—each varies from another, and even from itself in different places, in the mode of superposition, vertical and horizontal extent; in the number and position of the coal and limestone, and other beds, &c.

Almost all coal-fields are traversed by what are called faults, slips, hitches, or dislocations, by which the strata on one side is sunk to *a greater* depth, or raised to a higher level than the same beds on the other; or, in other words, a fault is a crack by which contiguous portions of a coal-field are thrown out of their original continuity. The term dyke is often erroneously given to such dislocations; hitch, step, or slip, is commonly applied to the smaller faults.

Coal-fields are often traversed by dykes, properly so called. These consist of trap rocks, or other foreign matter, injected into a rent or fissure in the strata, and occur in the form of walls or dykes. Sometimes they occasion the dislocation of the strata; but more frequently the same beds are found on either side of a dyke in the same plane. Coal-fields are also traversed by what are called backs and cutters; these cross each other, in general, at a determinate angle, and divide the mass of a bed into large rhomboids. These are of great use in the extraction of coal and other minerals, such as limestone, ironstone, or sandstone.

The organic remains of one coal-field have generally a strict analogy to those of another. The plants consist of the stigmaria, lepidodendron, sigillaria, calamites, ferns, &c. The fishes are almost always covered with enamelled rhomboidal scales, and the shells are both referrible to fresh and marine genera. In all these matters the Mid-Lothian coal-field may be regarded as agreeing with that of the west of Scotland. We can merely notice the many important beds of coal and limestone which occur in it—to enter into detail as to the number, nature, and effects of the numerous faults by which it is intersected, is not our intention. Those wishing for this and such other information as our limits hinder us from giving, must have recourse to the excellent memoir of Mr David Milne on the subject, to whom the geological world is much indebted for the very lucid description which he has given of this field.

The coal formation of the Mid-Lothians, like that of the west of Scotland, is divisible into the upper, middle, and lower series. The upper contains no limestone, and such shells as do occur are referrible to fresh-water genera. This series overlies a calcareous bed called the Caldcoats limestone, occurring on the shore at Joppa, at Magdalen-Pans, and Gilmerton. It is about three feet thick, and contains marine remains.

The coals which occur in the upper series, that is, the strata overlying the Caldcoats limestone, are 25 in number. The uppermost of which are wrought for the supply of the Edinburgh market, at Craighall, and Sherrifhall, in the neighbourhood of Dalkeith. The following is a section taken at New Craighall to the diamond coal:—

| | Feet. | In. |
|---|---|---|
| Blais or Shales, | 6 | 0 |
| Sandstone, | 4 | 0 |
| Blais, | 18 | 0 |
| 1st Coal, | 3 | 9 |
| Clay shale, | 3 | 0 |
| Sandstone, | 4 | 0 |
| Blais, | 12 | 0 |
| Sandstone, | 3 | 0 |
| Blais, | 6 | 0 |
| One-and-a-half Coal, | 1 | 6 |
| Sandstone, | 3 | 0 |
| Sandstone, Red, | 5 | 0 |
| Blais, | 3 | 0 |
| Blais, mixed with Sandstone, | 6 | 0 |
| Red and grey Sandstone, | 6 | 0 |
| Red and yellow Do., | 24 | 0 |
| Red Blais, | 12 | 0 |
| Sandstone, | 40 | 0 |
| Blais, | 5 | 0 |
| Sandstone, | 12 | 0 |
| Blais and yellow, | 19 | 0 |
| Red and white Sandstone in different beds, | 135 | 0 |
| Blais, | 4 | 0 |
| Splint Coal, | 5 | 0 |
| Sandstone and Blais, | 24 | 0 |
| Blais, | 12 | 0 |
| Sandstone, | 0 | 0½ |
| Sandstone, | 18 | 0 |
| Rough Coal, | 4 | 0 |
| Blais, | 42 | 0 |
| Sandstone, | 5 | 0 |
| Sandstone and Blais, | 8 | 0 |
| Beefie Coal, | 6 | 0 |
| Sandstone, | 36 | 0 |
| Grey bands of Sandstone, | 16 | 0 |
| Red Blais, | 30 | 0 |
| Red and white Sandstone, | 22 | 0 |
| Blais, | 28 | 0 |
| Diamond Coal, | 6 | 0 |
| | 750 | 6½ |

We have evidence in this portion of the coal field of Mid-Lothian, that red-coloured sandstones and shales are frequently associated with valuable coal; and though the occurrence of similar sandstones and shales in other localities may be accompanied by coal; yet, as mistakes in cases of this kind may be likely to arise, proprietors ought to have such deposits well examined by a practical geologist, in order to determine whether the strata truly belongs to the carboniferous series or not, before incurring the expense of searching for coal by boring or otherwise. A mining engineer, without a competent knowledge of the principles of geology, will be of little or no use in such investigations, and a geologist, on the other hand, without practical experience of the nature of coal-fields, would be still worse.

1. Coal.—This coal occurs at Joppa and New Craighall, and is from four to five feet thick.

2. The Splint Coal occurs at Joppa at a distance of eight fathoms, and is from six to seven feet thick; at New Craighall, Monkton Engine and Miller-hill, Sherrifhall, and Edmondstone, the distance from the jet coal is from twenty-nine to thirty fathoms, and thickness from four to six feet.

3. The Rough Coal lies from seven to seven and-a-half fathoms below the splint. It is wrought at New Craighall, from four to five feet thick. At Millerhill it is divided by a stone of four inches, and measures four feet inclusive. At Sherrifhall it is six feet in one pit, and only three and-a-half in another (No. 15). At Edmonstone it measures four feet two inches.

4. The Beefie Coal.—This coal occurs from six to eight

fathoms, generally eight below the rough coal. At Sherrifhall it is divided by a bed of rock, said to be nineteen feet thick. At Edmonstone the parting consists of only eight inches of clay. The entire thickness of the seam is from three to five feet. The localities where it is wrought at are New Craighall, Millerhill, Sherrifhall, Edmonstone, Pinkie-House, and Castlesteads.

5. The Diamond Coal lies from eleven to fourteen—commonly eleven—fathoms below the Beefie seam. At Monkton engine the thickness is only two and-a-half feet; but at Sherrifhall it is four feet ten inches; at Castlesteads, three feet; Pinkie-House, three and-a-half feet; and at Millerhill, four and-a-half, including fourteen inches of a stone.

6. The Jewel Coal.—This seam occurs from six to seven fathoms below the diamond coal. It is much esteemed as a good household coal in the Edinburgh market. At New Craighall it measures from four to five and-a-half feet; but at Monkton, Sherrifhall, Edmonstone, Pinkie-House, and Castlesteads, the thickness is from four to four and-a-half feet.

7. The Golden Coal lies seven fathoms below the jewel seam. It occurs, two and-a-half feet thick, at Millerhill and New Craighall, but is only eighteen inches at Sherrifhall.

8. The next coal is known by various names—such as the Dalkeith upper coal, the Cowpits splint coal, the diamond and Hunter's coal. At the New Eldin pit it is fifteen fathoms below the golden coal, where it measures three feet nine inches. At Niddry it is five feet ten inches; and at other places it is about three feet. It is the uppermost coal at Rosewell village and Cowpits.

9. Coal.—This seam occurs from ten to eleven fathoms below the former coal. At the New Eldin pit it measures three feet four inches; at Cowpits, five feet · and at Castlesteads, four and-a-half feet.

10. Coal.—This coal lies three fathoms one foot below the ninth coal, at Castlesteads, where it is three feet thick. It does not appear to be known anywhere else.

11. Coal.—This seam also occurs at Castlesteads, and is three fathoms two feet below the former coal. At Eldin, where it is an upper coal, it is two and-a-half feet; and at Castlesteads it measures about the same in thickness.

12. Coal.—This is a six-inch seam, lying eighteen and-a-half fathoms below the former.

13. Coal.—This bed lies within three feet of the surface, at Bannockrigg, where it is three feet thick. At Sherrifhall (No. 36 pit) it is within seven fathoms of the surface, and forms the uppermost coal—but it is only two feet in thickness. At Castlesteads it is three feet five inches, and lies five and-a-half fathoms below the thirteenth coal seam.

14. Little Eldin, Glass, and Salter's Great Coal.—On the shore at Joppa, where the beds are highly inclined; the seam is about eight feet thick, including four feet of clay. At this place it lies eighteen fathoms two feet below the eighth coal. At Niddry this coal measures four feet ten inches; at Sherrifhall, two feet four inches; at Eldin, one foot nine inches; at Skelty Muir, seven feet; at Bannockrigg, two feet five inches; at Whitehill, where it is the upper coal, eight feet; at Rosewell village, six to nine feet; Bridgedean, nine feet; Cowpits, two and-a-half feet; and at Castlesteads, where it is five fathoms below the fourteenth coal, two and-a-half feet.

15. Eldin Rough or Barr's Coal.—This is the uppermost coal at Sommerside, Rosewell, Jewelpit, and Pinkieburn, where it is respectively three feet ten inches, four and-a-half feet, and four feet thick. At Sherrifhall (No. 36), it is twelve fathoms below the Little Eldin coal, and two and-a-half feet thick; but in pit No. 27, it is three and-a-half feet. At Sommerside the distance is only six fathoms, and measures three feet ten inches —the general distance is, however, from ten to twelve fathoms, and the average thickness about four feet. The following are the localities, with the thickness at each ·—Eldin, four feet; Polten, three feet three inches; Skelty Muir and Bannockrigg, three feet four inches; Whitehill, three and-a-half feet; Rosewell village, three to three and-a-half feet; Barleydean, four feet ten inches; Pinkieburn, four feet; Cowpits, three and-a-half feet; and Castlesteads, five and-a-half feet.

16. Nine Feet, Sommerside, or Eldin Splint Coal.—This coal lies three fathoms below No. 16, in Sherrifhall (No. 36 pit); and two fathoms four feet at Sommerside. The distances are from eight feet to six fathoms; its localities and thicknesses are —Joppa, eight feet seven inches, with two feet of clay; across Brunstein and Duddingston, eight feet seven inches, including two feet of clay; New Craighall, five and-a-half feet; Niddry, five feet; Sherrifhall, three feet ten inches; Sommerside pit (No. 1), three and-a-half feet; Eldin, Polten, Whitehill, Rosewell village, Barleydean, and Aikendean, two and-a-half feet; Skelty Muir, two and-a-half feet; Bannockrigg, ten feet; Pinkieburn, two feet five inches to four feet; Cowpits, three feet; and Castlesteads, three and-a-half feet.

17. Coal.—This seam at Eldin is only eight feet below the last-mentioned coal; at Whitehill it is five fathoms two feet; at other places it occurs at intermediate distances. The thickness varies from two to four feet. It is found at Sherrifhall, two feet; Sommerside, two feet; Kelty Muir, three feet; Whitehill, four feet; Rosewell village, three feet five inches; Barleydean, two and-a-half to four feet; Aikendean, nine inches thick.

18. Fifteen Feet, Eldin's Jewel, and Cowfits Six Feet Coal.—The following table will show the thicknesses acquired by this very important coal bed in different places :—

| Localities. | Distance. Fathoms. | Thickness. Ft. | In. | Localities. | Distance. Fathoms. | Thickness. Ft. | In. |
|---|---|---|---|---|---|---|---|
| Joppa and Duddingston,... | 0 | 12 | 6 | Rosewell Jewel Pit,......... | 6 | 2 | 4 |
| New Craighall,.............. | 0 | 6 | 6 | Aikendean,..................... | 21 | 4 | 0 |
| Sherrifhall,..................... | 0 | 4 | 0 | Polten,............................ | 0 | 12 | 6 |
| Niddry,............................ | 5 | 7 | 0 | Bannockrigg,................... | 0 | 3 | 0 |
| Sherrifhall (No. 36),......... | 14 | 2 | 6 | Pinkie-House,................. | 0 | 6 | 0 |
| Sommerside (No. 1),........ | 14 | 1 | 10 | Cowpits,.......................... | 0 | 5 | 6 |
| Skelty Muir,.................... | 18 | 2 | 8 | Castlesteads,.................... | 0 | 5 | 0 |
| Whitehill,........................ | 6 | 2 | 4 | | | | |

This coal sometimes contains a few inches of parrot or cannel coal, as at Rosewell, Whitehill, Skelty Muir, and Aikendean,

19. Jenny Megoat's, or Four Feet Coal.—The distance of this seam from the fifteen feet coal varies from eleven to twenty-five fathoms; at Bannockrigg it is eleven fathoms; at Joppa, twenty-five fathoms; at New Craighall, fifteen fathoms; Niddry, thirteen and-a-half fathoms; Sherrifhall, twenty fathoms; Sommerside, fifteen fathoms from the surface; and at Melville Castle, twenty-two and-a-half fathoms. The thickness varies from two and-a-half to four feet.

20. Upper Melville, or Seven Feet Coal.—The distance of this coal from the last-mentioned seam is from four to eight fathoms; at Joppa it is fifteen feet thick, including two bands of stone six and-a-half feet thick, leaving eight and-a-half feet of coal—these bands at Duddingston thicken to nine feet. At Niddry the seam narrows five feet four inches; at Sommerside, four feet; and at Melville Castle, two feet ten inches.

21. This Coal is situated six fathoms below the upper Melville coal, and is three and-a-half feet in thickness.

22. This is a thin coal, known in Newmills level and Bryant's pit only.

23. This coal occurs in Newmills level, two fathoms one foot below the last-mentioned seam. Here it is only one foot four inches in thickness; but at Magdalene pans and Gilmerton it measures three and four feet.

24. This seam is only six inches on the shore at Joppa, but at Gilmerton it is two feet four inches, and is twenty-four fathoms distant from No. 24; at Newmills, the distance is said to be forty-five fathoms, and the thickness only seven and-a-half inches; at Bryant's, it measures one foot in thickness, and the distance is seventeen fathoms. The strata underlying this seam contain no coal at Joppa for 111 fathoms; at Magdalene pans for seventy-five fathoms; nor at Gilmerton for forty-one fathoms; but at these distances, in each of these places, there is the three-feet stratum alluded to at the commencement of this article, called the Caldcoats limestone.

The remaining beds of limestone and coal will be noticed in the next chapter.

(1) *Lithological.* From *lithos*, a stone, and *logos*, a discourse—pertaining to rocks. (2) *Stigmaria fecoides.* A plant which occurs in almost all the beds of a coal field, frequently with the leaves spread out from the stem in a parallel and in a horizontal direction. The stem is marked by alternating dots or scars, to which the leaves are attached. The leaves are long, and from a quarter to half an inch in breadth. The stems are sometimes found of great length, round or compressed. The stigmaria is considered to have been an aquatic plant. (3) The *Lepidodendra* have beautiful rhomboidal scars—are like those formed by the scales which compose the cone of the larger or common fir. The leaves are often attached. (4) The *Sigillariæ* have fluted stems, with alternating scars of different shapes. (5) *Calamites.* Plants allied to the equiseta or horse-tails.

## DIAL OF THE SEASONS.

### CHAPTER I.

The Dial of the Seasons represents the angles of incidence of the meridian sunlight—*i.e., the sun's declination*—as they change in conformity with the earth's annual motion in its orbit round the sun, causing, at our own latitude, the seasons of the year; and, at all latitudes, the seasons and climates of all parts of the earth.

The more direct angles, which are always present at the tropical latitudes, maintain constantly very warm temperatures, averaging, at a moderate elevation above the ocean, 88 degrees of Fahrenheit at the equator, about 76 at the tropics, and at least 80 degrees for the whole intertropical latitudes—*mean of night and day*—for the entire year; and giving to these latitudes the appropriate name of the torrid zone.

The oblique angles on the latitudes towards the polar regions of the earth, give but a comparatively feeble influence of sunlight, and the average annual temperatures of the arctic and antarctic circles, though softened for a few weeks of summer, are undoubtedly several degrees below zero; these are appropriately called the frigid or frozen zones.

As the temperatures most frequently spoken of, are those of the hottest or coldest hours of the day, it is proper to state distinctly, that the average temperatures here stated are those which are arrived at by adding the highest and lowest temperature of the whole twenty-four hours, and taking the mean between these as the average of the day.

The range and extent of this contrast of temperatures of the equatorial and the arctic, may be illustrated by those which are experienced at the extremes of the hottest summers and coldest winters. The annual average heat, for the days of the whole year at the equator, is greater than that of the hottest day ever felt at London—while the annual average cold of the arctic and antarctic circles is colder than the coldest day ever felt at London.

The intermediate portions of the earth, or the temperate latitudes—in nautical phrase, *the variables*—are receiving the sun's light at an angle which is intermediate, and which causes the temperate climates—varying, however, greatly by the changes of the seasons, and by their being a sort of battle-ground where the alternate winds and ocean currents, from the uninhabitable, impenetrable deserts of frost on the one side, and from the torrid zone on the other, conflict with and neutralize each other. The inland latitudes within ten degrees of the equator are, in fact, deserts of heat yet unexplored by civilized man; the intense action of the direct sunlight drying up the earth to a desert, unless on portions favourably situated for the reception of moisture, and consequently cooled and rendered favourable to vegetation by an abundant evaporation. Ross and Parry, and the Arctic and Antarctic explorers, return to tell their narratives of suffering and privation from the cold, but the explorers of Equatorial Africa and America have seldom or never returned; they have perished from the drought, the intense heat and malignant diseases of the torrid zone.

The colder temperatures consequent on elevation above the ocean level, which are estimated by Baron Humboldt to equal those of a degree of latitude further from the equator for every 328 English feet of elevation, are of course to be considered as local exceptions to the grand laws of climate.

The pictorial portions of the Diagram are designed to present characteristic species of the plants and animals, ocean beacons, headlands and scenery, in their appropriate latitudes; and also to represent the most remarkable monuments of the civilization of man, whose history and enduring memorials are wanting in the Arctic and Equatorial climates, and whose most fortunate developments are found to belong to the intermediate *isothermal* temperatures of the Temperate Zones, the central portions of which have produced the men of the highest intellectual and moral power, and, in every department, the noblest of human achievements. The homes of the more remarkable patriarchs, historians, philosophers, poets, statesmen, warriors, architects, astronomers, philanthropists, theologians, physicians, artists, and discoverers, belong neither to the Torrid nor the Arctic, but to a somewhat narrow zone of the Temperate intermediate climates.

This zone of the intellectual parallels undoubtedly widens with the progress of the arts and sciences of civilization, which, originating in the more fortunate localities of the Earth's surface, are diffused by the enterprises of peaceful commerce, or the force of arms; and are gradually adopted and made available by the imitative sagacity of the less intellectual inhabitants of the northern and southern countries. It is thus that the labours of men of genius, in extending the dominion of man over rude nature, vivify the aggregate intellect of nations and of the species.

The same remarks ought to be true in morals. If much is required from those to whom much is given, the moral influence of the more intellectual nations ought to be, though it is not always, beneficial to the less enlightened. The most fortunate climates do not exempt men or nations from degeneracy.

"Collateral to the main design, the Diagram may be employed to exhibit the connection existing between certain forms of disease, the climates and latitudes in which they prevail, and thermometrical ranges of temperature," as existing within certain parallels, constituting an important element in giving intensity to endemic diseases, and to those diseases which are epidemic only at certain seasons of the year in certain latitudes.

Secondary in interest only to the natural history of our own species, is the comprehensive study of the chemico-vitality of vegetation, and the physiology of animals as adapted to the various climates in which only they are found to exist, or *to reach their highest perfection.* In this view are comprised the sciences of comparative anatomy and comparative physiology, in their widest application to the entire world of animated beings, as they exist grouped each in its appropriate relation to the genial sunlight in the grand museum of nature.

The Dial, as it presents the relations of our earth's landscapes to the sun, at the different periods of its annual orbit, is a first lesson in terrestrial astronomy.

The Dial of the Seasons exhibits, first, the changes of the angle of the sun's light at the latitudes of London and Philadelphia at all seasons. The angles are those at 12 o'clock noon, when the sun is on the meridian. These changes of the angles of the sunlight are, in nautical and mathematical language, called the sun's declination.

The sun has north declination for the six months of the year, which comprise the summer of the northern hemisphere—this being the winter of the southern hemisphere. It has south declination for the other six months of the year, which comprise the winter of the northern hemisphere—this being the summer of the southern hemisphere.

The sun has no declination when it is exactly vertical on the equator. This occurs twice in the year, at the spring and autumnal equinoxes. It is only at those two moments of the year, when the earth, at the west point of its orbit, changes the zenith of the sunlight from south to north declination, on the 21st day of March; or at the east point of its orbit, from north to south declination, on the 23d day of September.

On the 21st day of March, the vernal equinox, the sun rises at 6 o'clock, due east, and at 12 o'clock, noon, is exactly vertical on the equator, 3,579 miles south of London, and sets at 6 o'clock, due west; the equinoctial day being exactly twelve hours.

The sun's light is then falling on all latitudes, both north and south of the equator, at angles which, if accurately measured at any point, or at all points, determine the exact latitude of such points, northern or southern. Thus, at the parallel of London, it is falling at an angle of 51° 28′ 39″; and at St. Petersburgh, at an angle of 59° 56′ 31″ north. At New Orleans, it is falling at an angle of 29° 57′ north; and at the same moment, on the parallel of Philadelphia, it is falling at an angle of 39° 56′ 57″ north—these angles being the index of the respective latitudes.

For a familiar illustration, the shadows of the palm trees of the south, or the fir trees of the north, or of any window-sill in the temperate latitudes, if accurately measured, determine latitude; while, at the same moment, the entire navies of the world, at least those which are in similar longitude, are taking the sun's altitude—in nautical language, the sun's declination —and thus determining their latitude.

On the 22d day of March, the sun rises about three-quarters of its own diameter, about 24 minutes of a degree northward of due east. Its altitude—the angle of its light at noon—is, to us in the northern hemisphere, about three-quarters of its own diameter higher; and the place of its setting about three-quarters of its own diameter north of west. It would thus apparently describe a higher arc in the heavens. If, for illustration, its apparent path of the 21st were visibly marked on the sky, its path of the 22d would be three-quarters of its own diameter, or 24 minutes of a degree, higher than its path of the 21st.

The sun was vertical on the 21st, at the equator. On the 22d it is vertical about twenty-four geographical miles north of the equator. It has acquired about 24 minutes of a degree of north declination. In the northern hemisphere, it has acquired about 24 minutes of a degree of additional altitude. In the southern hemisphere, it has lost altitude to the same extent.

On the 21st, the sun was vertical on the equator: it had no declination. The sunlight and length of day were equally divided between both hemispheres. The day was twelve hours long. On the 22d, all of the northern hemisphere has a longer day, and higher angle of the sun's light. All of the southern hemisphere has a proportionally shorter day, and a lower angle of the sun's light. It is obvious that only one-half of a globe can be in sunlight, and that as one side or hemisphere is thrown into more direct light, the other side is correspondingly thrown into oblique light.

From the 21st of March, the vernal equinox—when the earth is at the extreme west point of its orbit—till the 21st of June, the summer solstice—when the earth is at the extreme south point of its orbit—the sun rises every day further and further north of east, it is every day vertical at a parallel further north, is of greater meridian altitude in the northern hemisphere, and sets every day further and further north of west, increasing its north declination and its altitude daily, and describing a higher path in the heavens.

Let us suppose, for illustration, that the paths of the sun for every day were visible on the sky, and that the outlines of the suns of succeeding days could be traced; the sun of the 21st of June would rise forty-four suns' diameters, 23½ degrees north of east, would be forty-four suns' diameters higher at noon, and would set forty-four suns' diameters north of west—giving to the northern hemisphere its highest angle of the sun's light, and giving at London a day of about seventeen hours. The sun has then reached its extreme of nearly 23½ degrees of north declination, and is vertical over the tropic of Cancer, viz., *the northern turning point*, about 1,630 miles north of the equator, and about 2,949 miles south of London.

The sun's declination might be well illustrated by supposing a series of vertical towers accurately built, or of wells accurately dug, down which the sun would shine vertically every day in the year; those commencing at the equator on both sides would be about twenty-four miles distant from each other, while those next the tropics would be about a quarter of a mile. The sun's declination describes on the earth's surface a spiral line of advancing or receding incidence, of which the two tropics are the semi-annual limits.

From the 21st of June, daily, till the 23d of September, the earth returning on the eastern side of its orbit, the sun retraces every day a lower arc in the heavens, giving us every day a shorter day, and becomes vertical each day at parallels nearer and nearer to the equator, its north declination decreasing daily, till on the 23d of September, when the sun again becomes vertical on the equator, and we have the equinoctial day and night of twelve hours—the sun rising at six and setting at six o'clock.

At the moment of crossing the equator, the 23d of September—the autumnal equinox, when the earth is at the east point of its orbit—the sun has no declination, *i.e.*, is again exactly vertical on the equator. From the 23d of September, daily, till the 21st of December—the winter solstice, when the earth is at the north point of its orbit—the sun rises every day more and more south of due east, it becomes vertical every day at parallels more and more south of the equator, and thus acquires daily an increasing south declination. It continues to describe every day a lower and lower arc in the heavens, giving in the northern hemisphere shorter and shorter days, until the 21st of December, when it reaches its extreme of south declination, and the angle of the sunlight is most oblique.

On the 21st of December, the sun is vertical about 23½ degrees south of the equator, at the tropic of Capricorn, or southern turning point, about 5,202 miles south of London; the word tropic being derived from the Greek verb *trepo*, to turn. Our days in the northern hemisphere have shortened, and those in the southern hemisphere have lengthed in a similar proportion.

From the 21st of December, daily, till the 21st of March, the earth's motion brings the southern hemisphere every day vertical to the sun at parallels nearer and nearer to the equator, till the 21st day of March, when the sun is again vertical at the equator, and we have one more day of twelve hours—the sun having no declination, and rising at six o'clock and setting at six o'clock, in all parts of the world.

To recapitulate: On the 21st of March, and the 23d of September—the spring and the autumnal equinoxes—the sun is vertical on the terrestrial equator, divides its light equally between both hemispheres, gives us days of twelve hours, and its apparent path in the sky, to observers in all latitudes, is the celestial equator. On the 21st of June—the summer solstice—it is vertical on the northern tropic. Its path on the sky, to observers in the north temperate zone, is 23½ degrees, forty-four suns' diameters higher than the celestial equator. On the 21st of December, the sun is vertical on the southern tropic. Its apparent path, to northern observers, is 23½ degrees, forty-four suns' diameters lower than the celestial equator.

The path of the sun at the summer solstice is thus eighty-eight suns' diameters higher than at the winter solstice; the intermediate path, at the equinoxes, marks the celestial equator.

The Dial, though designed especially for the northern hemisphere, when reversed at opposite seasons, represents equally well the sun's declination for the southern hemisphere.

The comparative view of the sun's declination, which occupies the right of the Dial, represents the sun's declination as it occurs at five parallels of latitude.

At the equator, the declination is equally divided. On both sides it has 23½ degrees of inclination, which there means the same as declination. At both periods of six months, the angle of the sunlight, commencing at vertical, inclines to a declination of 23½ degrees, and returns again to vertical. Both periods of six months are equally summers. This is not quite true, but it is for a cause which will be treated in another chapter.

At the tropic, which is a latitude of 23° 28′, the angles for the summer six months, commencing at 23° 28′, diminish the north declination 23° 28′, and become vertical at the summer solstice, and return again to 23° 28′ on the 23d of September; while, for the winter six months, commencing at 23° 28′, they add the south declination 23° 28′, making 46° 56′, which is the angle at the winter solstice.

At Philadelphia, latitude 39° 56′, it is 39° 56′ less, 23° 28′ equals 16° 28′, quite a tropical angle at the summer solstice, and 39° 56′ added 23° 28′ equals 63° 24′, quite a wintry angle at the winter solstice. The Indian corn plant is the adopted pictorial characteristic, representing the parallel of Philadelphia.

At London, latitude 51° 28′, it is 51° 28′ less 23° 28′ equals 28° at the summer solstice, and 51° 28′ added 23° 28′ equals 74° 56′ at the winter solstice. St. Paul's is the adopted pictorial characteristic, representing the parallel of London.

At St. Petersburgh, latitude 59° 56′, it is 59° 56′ subtract

23° 28′ leaves 36° 28′ at the summer solstice, and 59° 56′ added 23° 28′ equals 83° 24′ at the winter solstice.

TABLE.

| Actual angle of incidence. Dec 21. | | South declination. Dec. 21. | | North declination. June 21. | Actual angle of incidence June 21. | |
|---|---|---|---|---|---|---|
| 23° 28′ | South | 23° 28′ | Equator. | 23° 28′ | 23° 28′ | North. |
| 24° 28′ | " | 23° 28′ | 1° north lat. | 23° 28′ | 22° 28′ | " |
| 25° 28′ | " | 23° 28′ | 2° " | 23° 28′ | 21° 28′ | " |
| 26° 28′ | " | 23° 28′ | 3° " | 23° 28′ | 20° 28′ | " |
| 28° 28′ | " | 23° 28′ | 5° " | 23° 28′ | 18° 28′ | " |
| 33° 28′ | " | 23° 28′ | 10° " | 23° 28′ | 13° 28′ | " |
| 43° 28′ | " | 23° 28′ | 20° " | 23° 28′ | 3° 28′ | " |
| 46° 66′ | " | 23° 28′ | 23° 28′ " | 23° 28′ | Vert. tropic of Cancer. | |
| 53° 28′ | " | 23° 28′ | 30° " | 23° 28′ | 6° 32′ | South. |
| 63° 24′ | " | 23° 28′ | 39° 56′ Philadel. | 23° 28′ | 16° 28′ | " |
| 74° 56′ | " | 23° 28′ | 51° 28′ London. | 23° 28′ | 28° | " |
| 83° 23′ | " | 23° 28′ | 59° 56′ St. Petbg. | 23° 28′ | 36° 28′ | " |
| 90° | " | 23° 28′ | 66° 32′ Arc. | 23° 28′ | 43° 4′ | " |

The Dial of the Seasons exhibits to the eye, not only the comparative obliquity and directness of the sunlight at the summer and winter periods of the year, but also the comparative rapidity of the sun's declination at the spring and autumnal periods—the equinoctial periods of the year—and its slowness as it approaches the solstices, portions of the year when the earth is sweeping the northern and southern curves of its orbit, and the sun's declination alters so slowly as to be said to stand still.

The spring and the autumn are the west and the east portions of the earth's orbit; to us in the northern hemisphere, the southern portion of the orbit is summer—the northern sweep of its orbit is winter.

The earth's motion is not in an exact circle. It has, to a small extent, an elliptical orbit. We may at present, however, contemplate it as not greatly differing from a circle.

Let us, for illustration, compare the earth in its orbit to a horse in a race-course. Let our position be the centre of the race-ground. Let the course be divided into twelve equal divisions, corresponding to months. The earth, or horse, at the west point of its orbit, is moving south, and is then making south for a large part of its motion. For the first month, one twelfth of the circle, the southing is large, though the direction is slightly changed to an east direction. For the second month, the direction constantly curving east, the southing is much less. For the third month the direction is chiefly east, the southing is small and still diminishing, till, in about ninety-three days from the west point, as it reaches the extreme south of its orbit, its course is due east.

Continuing its course, the earth commences the east sweep of its orbit. Its motion, very gradually at first, but with a constant curvature, changes more and more into a north direction, till, in ninety-three days, at the easternmost point of its orbit, it has a course north. This is the autumnal equinox.

Continuing its course northward, our northern hemisphere is rapidly thrown into the oblique light of autumn and winter, but curving continually into a west direction, the untiring planet reaches, in about eighty-nine days, the northernmost node of its orbit, its course being then due west. This is the winter solstice.

Sweeping onward, its course, at first very gradually, but increasingly, curves into a southern one, till another period of eighty-nine days brings it again to the westernmost point of its orbit, its course being south. The spring, the vernal equinox of another year, is present in the northern hemisphere.

It is thus, in accordance with the pauseless whirl of our planet, through an orbit of six hundred millions of miles, that spring-time and harvest, autumn and winter, proceed in incessant succession.

We have alluded to the ellipticity of the earth's orbit. From this one of the results is, that the sun is eight days longer on the northern side of the equator than on the southern. Our summer is the aphelion portion of the earth's orbit. The earth is then more distant, and its motion is slower. Our winter is the perihelion portion of the earth's orbit: the earth is nearer the sun, and its motion is more rapid. Our summer of the northern hemisphere is eight days longer than that of the southern hemisphere.

The earth is three millions of miles nearer the sun in our winter than in summer, but it is the oblique direction in which the angle of the sunlight reaches us, which gives us the diluted and feeble light of winter.

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EXPLANATION OF THE PICTORIAL BASIS OF THE DIAL OF THE SEASONS.

The pictorial portions of the Dial are designed to represent characteristic species of the plants and animals, and memorials of human civilization, in their appropriate latitudes.

They are reduced from a large picture, of which they are but mere hieroglyphics, as the larger picture is but a very feeble hieroglyphic of the grand reality of the living landscape which it is designed to suggest to the mind of the reader.

Of the 100,000 species of plants known to naturalists, only 40 species are very imperfectly and diminutively represented on the Dial. Each hieroglyphic may thus be considered to represent 2,500 species.

Of the 7,000 known species of birds, two only are poorly delineated.

To do justice to the idea, an entire picture should be chiefly devoted to each department of natural history. For instance, one which should attempt to group, in their appropriate scenery in the uncaged aviary of nature, the gay-plumaged birds of the tropics, the song-birds of our temperate latitudes, and the hardy land and water-fowls which inhabit the north.

The young seaman should endeavour to form a comprehensive idea of the ocean, covered with the canvas of commerce, veering to every breeze, as one grand continuous marine picture from the equatorial, where, fleckered with thunder-storms and coral islands, it is glowing beneath the tropical sunlight, to where, fading into twilight and darkness, the auroræ boreali corruscate from behind the rugged outlines of its polar icebergs.

The influence of climate upon man, upon the arts and necessities of life, upon intellectual and moral character, upon human history and civilization, is a subject of great extent and interest, to which whole chapters ought to be devoted.

At present we give only the names of the illustrations, commencing at the Equator. Mean annual temperature, 88°.

1. The banyan tree.
2. The negro.
3. The cochineal plant.
4. In the distance the volcano of Cotopaxi in the Andes.
5. The giraffe.

6, 7, and 8, group the cardia papaya, palm tree, and the climbing black-pepper plant.

9. The elephant.
10. The cocoa or chocolate plant.
11. The banana.
12. The tiger.
13. The small plant whose root is the ginger.
14. The cocoa-nut palm.
15. The anaconda.
16. The socotorine aloe.
17. The pine apple.
18. The coffee tree.
19. Sugar cane.
20. The rhinoceros.
21. The orange tree. This is the tropic emblem. Mean annual temperature, 76°.
22. The Palmetto palm.
23. The scarlet flamingo.
24. The rice plant.
25. The tea plant.
26. The camelia.
27. The date palm tree.
28. The pyramids. Cairo, Egypt, lat. 30° 2′. New Orleans, Louisiana, lat. 29° 57′. New Orleans and Cairo differ but five miles in latitude, and have a nearly similar mean annual temperature of about 72°.

29. The camel.
30. The temple of Jerusalem, Judea. Lat. 31° 46′.
31. The cotton plant of commerce. The greenseed variety of cotton grows well only within parallels of from about 31½ to 33½ degrees of north latitude. It is placed on the centre of this, lat. 32½.
32. The fig tree.
33. The pagoda of Nankin, Central China.
34. The buffalo of the North American prairies.
35. The tobacco plant.
36. The olive tree.
37. The Parthenon at Athens. The capitol at Washington is a few minutes north of Athens, so that they may be considered emblems of the same parallel.
38. The peach tree.
39. The Indian corn plant. This may be taken as the emblem of the latitude of Philadelphia. Baltimore is but about half a degree south; New York is about three-quarters of a degree north of Philadelphia.
40. In the distance, the mountain perspective indicates the Caucasian mountains, which have given a name to the most intellectual variety of the human race.
41. Mount Ararat, which is a little south of the 40th parallel, is very nearly the exact latitude of Philadelphia.
42. The dark spot on Mount Ararat, the ark. This is delineated as marking the locality of the patriarchal civilization, the vale of Shinar, the sources of the Euphrates and the Tigris, the fountains of sacred history.
43. The vine.
44. The Coliseum of Rome.
45. The horse.
46. The apple tree.
47. Wheat.
48. The pumpkin.
49. The ox.
50. The oak tree.
51. Sheep.
52. Barley.
53. The church of Notre Dame, Paris.
54. Ocean and emblems of commerce.
55. St. Paul's, London.
56. The roebuck.
57. The potato plant, emblem of lat. Dublin.
58. Rye.
59. The castled hill in the distance, Edinburgh.
60. The brown Russian bear, lat. Moscow.
61. Fir trees.
62. Flax.
63. Hemp.
64. Turnips.
65. Oats, the most northern of the cereal grains.
66. The birch tree.
67. The larch.
68. The moose deer.
69. Hunter and dog after wild fowl, the wild goose.
70. Laplander and reindeer.
71. Esquimaux and dogs.
72. Icebergs.
73. Polar bear, the last animal at the north.
74. Man, who for short excursions penetrates farthest, but gladly hastens back from the uninhabitable north.
75. Icebergs.

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#### OCEAN SCENE, COMMENCING AT THE EQUATOR.

The moderately elevated land, N. lat. 3°, is Cape de Norte, the mouth of the Amazon, east coast of South America.

The mean temperatures of warm parallels of the ocean are usually several degrees cooler than on land in similar parallels.

The mountain, lat. 7°, is Adams' Peak, Isle of Ceylon, lat. 7° 6′ N.

The ship, lat. 10°, may be considered as a homeward-bound East Indiaman.

The Palm-tree island, lat. 13°, is one of the horse-shoe shaped coral islands of the tropics. The little boat is intended for a Malay prow.

At lat. 15° to 20°, is represented a ship under close-reefed topsails, and a typhoon or hurricane, one of those exaggerations of our thunder storms, which, though not of great extent, are very severe, and of which perhaps hundreds are at all times roaring over the tropical latitudes of the ocean. Thunder storms are less frequent in the temperate latitudes, and very rarely occur in the north.

Lat. 23° 9′, is the Moro castle at the Havana, which, as it is within twenty miles of the tropic of Cancer, is used as a landmark of the tropic.

The vessel, lat. 25°, is intended for a Baltimore clipper-built West India trading schooner.

The mountain in the distance, lat. 28° 13′, is the peak of Teneriffe.

The pagoda is intended for the pagoda of Nankin, China, lat. 33° 30′.

Lat. 36° 5′, is the rock of Gibraltar, with a Spanish boat in the foreground.

Lat. 38°, a Greek felucca, the promontory of Sunium, with the ruins of the temple of Minerva in the distance.

Lat. 40°, an Italian polacre, Mount Vesuvius in the distance.

Lat. 43°, a Genoese vessel, indicates the home of Christopher Columbus.

Lat. 44°, may represent the largest American man-of-war, the *Pennsylvania.*

Lat. 46°, is the *Great Western*, the celebrated English steam-packet ship, from Bristol to New York.

Lat. 48°, the sail on the horizon may be a Dutch vessel.

Lat. 49°, a French frigate.

Lat. 50° 8′, the Eddystone lighthouse, Land's-End of England, and a ship in a storm.

Lat. 53°, on the horizon a Danish vessel.

Lat. 55°, a Swedish vessel.

Lat. 57°, a Prussian vessel.

Lat. 57° 38′, the Scaw, at the entrance of the Cattegut, mouth of the Baltic.

Lat. 59°, a Russian vessel.

Lat. 60°, a Norwegian vessel.

Lat. 62°, an American whale ship.

Icebergs.

Lat. 63°, Mount Hecla in Iceland, an Esqimaux boat, a polar bear on a field of ice.

Icebergs.

The aurora borealis.

We are, to our own observation, in the middle of the universe. Our knowledge of what is around us must begin from a point of which we are the centre. Our own daily and yearly relations to the sun are the seasons of our own landscape, those of the different latitudes constitute the climates of the globe we inhabit. These are, perhaps, the first and most obvious and impressive lessons in terrestrial astronomy. To explain these is the purpose of the Dial of the Seasons. The dial is an illustration of the sunlight as it falls on our planet.

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#### GENERALIZATION OF THE LAWS OF LIGHT.

From the preliminary consideration of the sunlight, as it falls on our own planet, it is natural to pass to the illustration of the laws of light as it expands in the universe, and to the *generalization of the laws of light.*

Light is subtle and ethereal; men differ as regards its nature. One thing is certain—the absence of light is darkness; it is the cause of which seeing is the effect. Without it, our noble sense of sight would be useless.

Light is a subject of unbounded extent and interest—equally worthy of our investigation, whether considered in the grand or the useful, the illimitable or the infinitely minute developments of nature continually occurring around us; or in the wonderful adaptation and exquisite susceptibilities of those organs of vision which receive its most minute and feeblest

impressions, and by some inscrutable association with the operations of the mind, render them immediately subservient to the simplest wants of existence, or the most exalted efforts of intellect.

From the properties, nature, and existence of light in our solar system, we derive laws which we shall attempt to illustrate, and which enable us to contemplate it as the *omnipresent traverser of infinite space*—pouring from its eternal reservoirs into a theatre where only its nature could be illustrated, and which it alone could illumine.

This sublimated ethereal substance, according to the inspired Hebrew historian, was spoken into existence by the first fiat of the Eternal, and originated in the incipient act of creative energy on rude and darkling chaos. Holding an intermediate relation to matter and immaterial existence, and triumphing in the inconceivable velocity and infinite extent of its emanations over time and space, it is a sort of angelic messenger from the throne of the Omnipotent to the boundlessness of universal creation.

It is certainly the most magnificent prototype which physical creation affords of the omnipresence of Deity, and of the unity of that self-existent universal energy which, while it "spreads undivided" and "operates unspent" in the worlds of matter and of mind, is continually revealing to intelligent creation the infinity and benignity of creation's Author.

Mankind, in the earliest ages, as by universal consent, had invested light with the attributes of Divinity. The most barbarous nations of both hemispheres, as well as those on the delta of the Nile, the plains of Chaldea, the mountains of the Caucasus, and the shores of the Ægean and the Adriatic, worshipped the sun as a benignant deity from their earliest traditions.

The planets, and the starry vault beyond them, as their periodical revolutions marked the lapse of time, and the returning seasons of seed-time and of harvest, to the transient generations of men, could not but inspire a degree of sublimity and of devotional sentiment among the rude wanderers on the banks of the Missouri, the Niger, and the Ganges, as well as among those nations whose mythology and whose rapturous poetry had taught them to view the constellations of heaven as no other than the resting-places of their translated heroes, and the happy abodes of the immortals.

The examination of the physical properties of light was, however, an investigation but little known to the ancients, and our present knowledge has been a gradual consummation of the experience of many ages.

Of the philosophers of antiquity, Plato was the first who has left us any observations on the subject. He considered vision to be occasioned by minute particles, continually flying off from the surfaces of bodies, which met with other particles proceeding from the eye.

This doctrine, if we may venture the suggestion, appears to have been the basis on which his pupil, Aristotle, subsequently founded his favourite theory of ideal forms, "phantasma," or species, a celebrated doctrine which was cherished as a sacred legacy by the philosophers of nineteen centuries, and may be referred to as one of the most remarkable proofs which history affords of the tenacious influence of received dogmas, sanctioned by authority and the assent of ages.

In order to account for our intellectual consciousness of the colour and outline of objects, Aristotle supposed the existence of a sort of semi-material phantom or image of everything, perfectly like the original in every respect, but possessing a power of acting as a medium between gross matter and our intellectual perceptions. Thus creating a duplicate of nature, in order to understand creation as it exists.

Our words, "idea" and "species," are enduring relics of this remarkable theory. The example of Aristotle has been not unfrequently followed by the philosophers of the subsequent ages, who have often succeeded in establishing theories by placing at proper distances their intervening phantasma, and thus led on their confiding followers to most erroneous conclusions.

Des Cartes considered light as an *invisible* fluid, present at all times and in all places, but requiring to be set in motion by the presence of fire, or some other cause capable of exciting it.

Malebranche, another French philosopher, offered a modification of this theory. He supposed light to be communicated by a sort of vibrations, in a manner analogous to those of sound—the impulses originating from the presumed motion of the particles of luminous bodies among themselves; as, for example, the flickering of flame, the agitation of water, or the intellectual or phrenal vibrations of Dr. Hartley.

But to develop the true nature of this most interesting substance, was reserved for the illustrious author of the immutable doctrine of gravitation.

Sir Isaac Newton concluded that light is a material agent, not fluid, but consisting of infinitesimal particles, and endowed with a repulsive energy, the reverse of that which governs the grosser forms of matter—an energy which causes it to radiate, with inconceivable velocity, *in straight lines* from the point of emanation, *i.e.*, the luminous body.

Attempts to ascertain the degree of the velocity of the motion of light, were made by Galileo early in the seventeenth century, by experiments at known distances on the earth's surface. But he found it impossible for him to detect any observable difference from absolute instantaneousness.

Roemer, a Danish astronomer, patronised by Louis XIV., in the course of his observations on the immersion of Jupiter's satellites at different periods of the year, and when the earth was in different portions of its orbit, discovered that those satellites are seen to be eclipsed when the earth is in the portion of its orbit nearest to Jupiter, eight and a quarter minutes sooner than the calculated time; and that, when the earth is in the opposite portion of its orbit, most distant from Jupiter, these eclipses happen eight and a quarter minutes later than the true time. He thus ascertained that the motion of light is not instantaneous, but that it occupies about sixteen and a half minutes in passing over or through a space equal to the diameter of the earth's orbit; and consequently, that the light of the sun occupies eight and a quarter minutes in passing to the earth, which is about two hundred thousand miles per second, or twelve millions of miles per minute.

Doctors Halley and Bradlee have since confirmed these results. The objections suggested by Dr. Franklin have been satisfactorily answered, and they are among the received data of astronomers.

It is therefore probable, that if the more distant planets in our system had not existed, the velocity of light would never have been observed.

Dr. Horsley has estimated the ultimate particle of light at less than one-millionth of a cubic inch.

The Chevalier de Arne has concluded that a continuous sensation, or consciousness of light, may be produced on the retina of the eye, by the arrival of a particle of light every seventh of a minute.

On this hypothesis, the distance in space of the successive particles of light on the same line, will be thirty thousand miles.

Every conceivable or observable point of the sun's surface must be a distinct radiating centre; and every point of the moon's surface a reflecting centre. This is evident from the fact, that a small opaque or less radiant spot on either is readily perceived. The velocity of direct and reflected light are considered to be equal.

Huygens, a Dutch astronomer of the seventeenth century, suggested that there might be "stars at such an immense distance, that their light had not yet travelled down to us since the creation."

This hypothesis has not been disproved; it is, in fact, sustained by the observations which the elder Herschel, by means of his gigantic telescopes, has been able to make in the remote ultra-planetary space.

The idea of Huygens pictures but a solitary pencil of light, travelling from some immensely distant star for six thousand years, at the velocity of twelve millions of miles per minute, but not yet having reached us, to make its origin visible at our earth. It is only *generalizing* this idea to believe, that the first created light of our sun, and that of every other star in

the firmament, still extends itself in all directions into illimitable space; maintaining, in all its wondrous inter-radiations, the distinct proportionate visibility of its innumerable suns, at any and every point of infinite space where the eye of an observer, or the lens of a telescope, can be imagined to exist.

This view of omnipresent, minutely inter-radiating light is important to science, if it disproves, as it not improbably does, the undulatory theory of light, which many modern astronomers, among whom are Whewell and the younger Herschel, have been inclined to entertain, and restores to well-deserved authority the Newtonian doctrine. Neither theory, however, can at present be considered as established.

The entire co-instantaneous action of the laws of light and of gravitation, existing in the expanse of the heavens, the phenomena of day and night and of the seasons, the whole vegetable and animal world in all climates and latitudes, and one thousand millions of our fellow-creatures, all contemporaneously existing, as light and shadow succeed each other, in pauseless succession, on the revolving globe, is too vast an idea for immediate conception. It is a subject of deliberate study; and to make this study more easy and popular, is the design of the present pages.

A vivid and adequate idea of our own planet is, we conceive, an indispensable introductory to the comprehensive conception of the vast scene of the heavens around us. The most distinguished of astronomers, Kepler, and Newton, and Laplace, have incontestably demonstrated the proportions of our earth to the solar system to be so exceedingly small, that at the larger and more distant planets, of which our sun is the centre, the earth would be absolutely invisible to the human eye. Jupiter is 1,400 times the bulk of the earth, and the visibility of the earth at Jupiter is, of course, in proportion; it is that of an orb $\frac{1}{1400}$ of the bulk of Jupiter, as it appears to us.

The greatest mathematicians—the most distinguished adepts in the laws of proportion and the relations of numbers, and in those abstract symbols and modes of calculation which establish, on irrefutable data, the most amazing results in the vastness of the universe around us, we are inclined to believe, from the narrowness of the human intellect, have hitherto seldom combined, with their profound contemplations of the heavens, an adequate conception of their native planet—

> "One science only does one genius fit,
> So vast is art, so narrow human wit;"

or at least they have not been so happy in their illustrations as to leave nothing to be desired.

## SANG'S PLANOMETER, OR SELF-CALCULATOR OF SURFACES.

This planometer, which was exhibited at the Crystal Palace, in Class X., No. 338, is the invention of Mr. J. Sang, of Kirkaldy. It is described as a self-acting calculator of surfaces, and is used for ascertaining the area of figures drawn on paper. For this purpose the operator is merely required to guide the point of a pen attached to the instrument round the outline of the figure, however irregular it may be. Indeed, it is chiefly in measuring irregular figures, the areas of which cannot be easily computed by the ordinary methods of calculation, that this ingenious instrument is found most useful. Figures of great irregularity of outline cannot be subjected to accurate admeasurement by scales, without much labour and frequent repetition of the process. Sang's planometer may be employed with advantage in measuring figures of any form, but its peculiar recommendation, which promises to bring it into general use, is the singular facility and despatch with which it exhibits the area of the most irregular surfaces, so as to indicate, from good maps, with wonderful accuracy, the relative extent of countries, and their subdivisions. It is not only useful to the student of physical geography, geology, and other branches of study in which maps are used, but it is well adapted also for the use of surveyors of land and engineers.

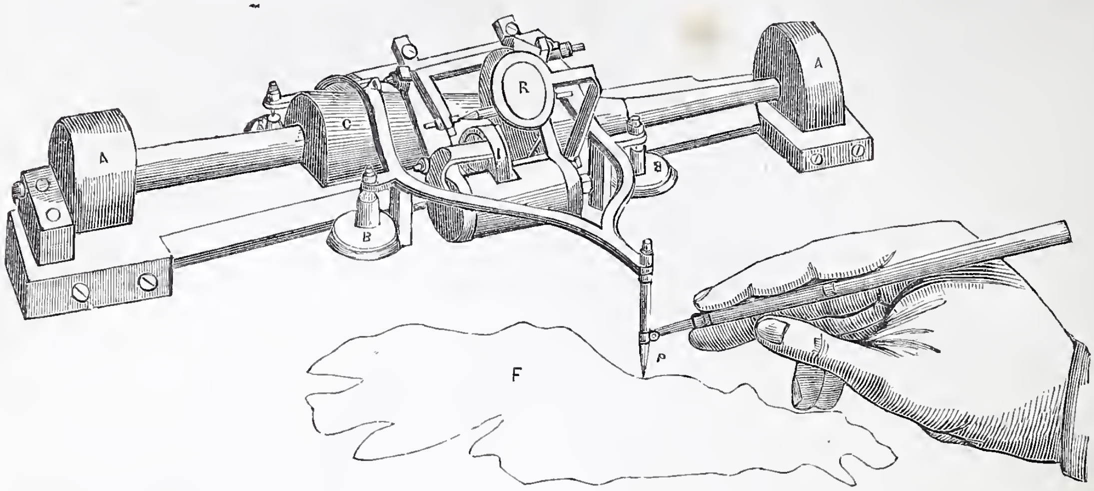
In using the planometer (see engraving), it is to be laid on or beside the figure in such a manner, that the tracer, P, can be carried round its outline. A handle is attached to the tracer, by which it is guided like a pen. It is first slightly pressed into the paper, so as to produce a small mark, and then it is carried round the outline of the figure until it again arrives at the mark. The index having been observed when the tracer was first put in motion, is again read when the latter has completed the circuit, and the difference between the two readings gives the area of the figure in square inches, and tenth and hundredth parts. The index may be put at zero when the motion commences, but the differential method, which is not attended with much trouble, is considered the best. When the boundary is not irregular, but consists of straight lines, a plane ruler is used with advantage in guiding the point of the tracer.

There are two indices attached to the instrument—one of silver, and the other of brass. The numbers engraved on the silver index indicate square inches, which are divided by lines into tenths, and farther, by a common vernier, into hundredth parts. By means of this index, the measurement of any surface may be taken, not exceeding twenty inches. By the brass index, the divisions are carried as far as 100 square inches. The instrument sent to the Exhibition would measure any figure not exceeding 4½ inches in breadth, and 22 in length. The area of larger figures might be taken by dividing them into sections with pencil lines, and measuring each separately. The instrument is therefore easily applied to figures of any extent of surface. The only adjustment required is when the instrument is lifted out of its case, to make the two indices read zero at the same time. This is readily done by lifting up the brass one, and turning it a little forward or backward. When the tracer is carried round the figure towards the right, like the motion of the hands of a watch, the reading on the indices increases; when in the opposite direction, the movement of the indices is towards zero. In either case, it is only necessary to take the difference between the first and last readings.

The mode in which the instrument operates is as follows: When the tracer is moved round the figure, the whole instrument moves with it on the rollers, A A, but only backward or forward, and not from side to side. The rollers are attached to the same axis, on which, or constituting part of which, is the cone, C, which also revolves with them. The two rollers are exactly of the same diameter, and therefore, in moving up and down the paper, their axis, which is also that of the cone, is always parallel to itself. Any lateral motion of the tracer does not affect these rollers, which only move backward and forward, and thus describe the length of the figure. The lateral motion of the tracer, corresponding to the breadth or the ordinates of the figure, is indicated by the action of four friction rollers, of which three, B B B, are shown in the engraving. These carry a frame, to which the tracing point is rigidly attached, and moves to the right or left with the latter, parallel to the surface of the paper. The index-wheel, I, is attached to this frame, and the edge of it touches the cone in that line which it is possible to trace upon it horizontally, or parallel to the paper. The lateral motion of the frame is also parallel to this line, so that the edge of the index-wheel always touches the cone and revolves with it. It is obvious that when the index-wheel is moved towards the base of the cone, or, in the figure, towards the left, by the lateral motion of the tracer in that direction, its revolution will be more rapid in proportion to the increased circumference of a section of the cone at that point, which is in proportion to the greater distance from its apex. The total revolving motion of the index-wheel is therefore in proportion to the motion of the tracer up or down the paper (indicated by the rollers, A A), multiplied by the extreme right and left distance of the wheel from the apex of the cone. Hence, when the tracer describes any complete perimeter, the whole rotatory motion of the index-wheel, I, represents the algebraic sum of the products of ordinates to every point in that perimeter, multiplied by the increment of their co-ordinates, which gives the area of the figure.

As any error arising from the imperfection of this instrument multiplies itself in the shape of a product, the utmost

care and mechanical skill are required in its construction, to give correct results. The specimen exhibited in the Crystal Palace, although it was the first model made by the inventor's own hands, performed its work with wonderful accuracy. Where great precision is required, the area of regular figures may be more accurately found by the ordinary methods of a



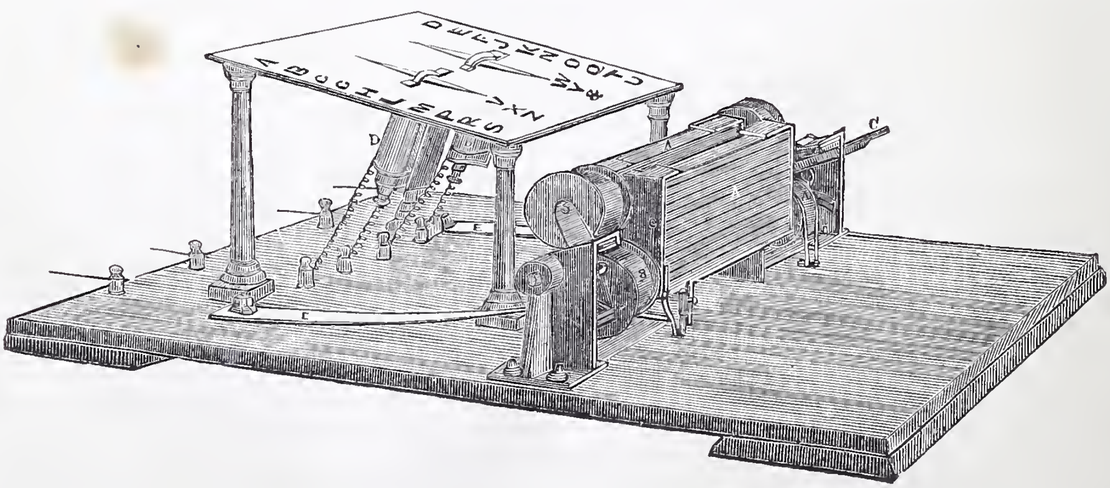

scale and calculation; but in measuring irregular figures, the instrument, if well made, is decidedly preferable both for accuracy and despatch, and its indications are sufficiently near the truth for all ordinary purposes, whatever be the form of the figure: so that, for the uses which we have already mentioned, we believe it is likely to be generally adopted in practice.

## THE MAGNETO-ELECTRIC TELEGRAPH.

The Magneto-Electric Telegraph Company has obtained a charter of incorporation for working out Henley's patent. The act received the royal assent on the 1st of August, 1851. The important practical improvements comprised in this patent may be thus summarily described. The invention entirely dispenses with the use of voltaic batteries of every description, together with all the complicated machinery for making and breaking contact. The circuit is affirmed to be always complete, always ready for action at a moment's notice without trouble or preparation, and entirely independent of those multiplied casualties which have hitherto attached to every application of the voltaic force to purposes of telegraphic communication. The necessary currents are thrown in circulation by the movement of conducting bodies of appropriate construction before the poles of a magnet, and the manner in which this is effected so as to insure results the most certain and the most lasting, will be readily understood by reference to the annexed engravings.

The instrument is represented complete, out of its case, in fig. 1. It consists of two distinct parts—one for producing and transmitting the current in the required direction, and the other for receiving its indications from a distant station.

Fig. 1.



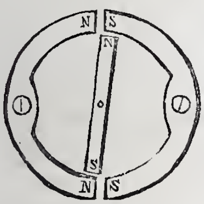
The producing and transmitting apparatus is shown to the right of the engraving. It consists of two compound permanent bar-magnets, A A, placed horizontally, side by side, about an inch apart, with their opposite poles in juxtaposition. Two soft-iron armatures, B B, turning on separate axles, are placed over against the poles, and nearly in contact with them. These

armatures are terminated by cylinders, which are wound with long coils of covered copper-wire, continuous and undivided at each end, and, with the soft-iron cores of the armatures which support them, are moveable in an angular direction by means of two levers or handles, c c. The range of motion of these levers is limited by india-rubber stops, fixed in the brass frame of the apparatus. The ends of the permanent bar-magnets are capped with rectangular pieces of soft-iron, which project inwards, so as to leave an interval of not more than half an inch between the poles—an arrangement by which the magnetic power is effectually preserved and concentrated.

The receiving or indicating part of the instrument consists of a dial mounted on four pillars in an inclined direction, this being the best for reading the indications, besides reducing to one-twentieth part the friction of the needle-pivots. Two electro-magnets, one to each needle, are fixed under the dial. The attempts previously made to apply electro-magnets to the deflection of the needle have never succeeded, in consequence of the residual magnetism left in the bar after the battery current had ceased to flow. In the magneto-electric telegraph this difficulty is overcome. Two semicircular pieces of short-iron, as shown in section in fig. 2, are screwed to the poles of the electro-magnet, so as to convert the two poles into four. In the centre of the broken circle thus formed (see fig. 3), a short and well-magnetized needle of hard steel is suspended, the axis of which is prolonged through the dial, and carries the index or pointer. The mode in which this ingenious improvement operates in causing the required deflection of the needle, will be at once understood from the plan in fig. 3.

Fig. 2.

Fig. 3.

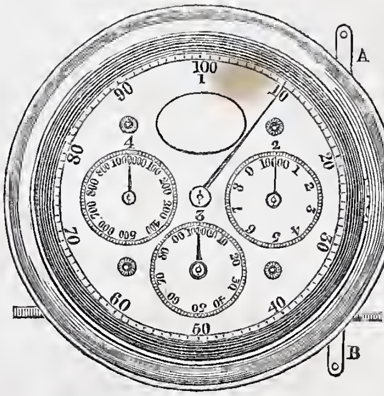



Now, returning to the first part of the instrument, either of the levers, on being pressed down, causes the ends of the armature to which it is attached, to change their position with reference to the poles of the magnet. This, of course, induces a current in the coils of copper-wire which surround that armature, and the circumstances are such that the current so induced is made to circulate round its appropriate electro-magnet, both at the transmitting and receiving stations. The needles on which these act are thus deflected to their respective stops with a perfectly dead beat, and there they remain so long as the depression of the lever is continued; but, as soon as the lever is allowed to spring back, the armature again reverses its position, another current is induced in a contrary direction, and the needles return, with another dead beat, to the point which they have just quitted. By varying and combining these movements, as in the common electric telegraph, the several indications are given, corresponding to the letters of the alphabet.

This instrument is obviously far in advance of its predecessors, and is regarded by good judges as fitted to render almost perfect the system of telegraphic communication. One of its great advantages is the unmistakeable decision which is given to its various indications by the dead beat of the needle, instead of the uncertain vibratory motions of the needle in the ordinary instruments. But that which is described as the most curious and striking part of the whole arrangement, is the character of the electric current which is thrown into circulation. On this subject, an intelligent writer in the *Mining Journal*, of August, 1851, when the act of the Company had just passed, writes as follows:—"It (the electric current) travels just where it is required to travel, avoiding all those accidental deviations which exercise such an exhausting effect upon the ordinary voltaic current, and sometimes render it utterly powerless in the transmission of intelligence. A very fair sample of this fact was exhibited a short time since upon the South Devon Railway, where, subject to the most imperfect insulation, and the worst conceivable weather for telegraphic purposes, the communications were not once interrupted, or even impaired. The experiments, also, which were recently performed in Hyde-park, and across the Serpentine, were even more strongly confirmatory of the practical excellence of the arrangement, for there all was conducted under the public eye; and though the tests to which the apparatus was subjected were of the most severe and studied character, it was not found to fail in a single instance. And this leads me to speak of something very strange, and apparently anomalous in the quality of the current itself. It will not divide and weaken its energies by passing in any quantity down the posts of the line when these are wet and deficient in insulating power; nor will it be diverted from its course even by a direct contact with a body of water; and yet, in using the earth as a part of the circuit, it is found that the smallest and most imperfect contact is sufficient for the purpose. Within the last week a short line was brought into operation at the Welwyn tunnel, on the Great Northern Railway. Those who went to set it to work, found that the engineer had neglected at one of the extremities to supply an earth-wire. A spade happened to be lying close by, not sticking in the ground, but merely lying on the surface of the dry chalky soil. A wire was hastily attached to this, and instantly the circuit was not only complete, but was all that could be desired, for during the whole day communications continued to pass through this medium. I feel convinced, indeed, from experiments that have been made, that a penny piece, soldered to the end of the wire, and thrown upon the ground, would be quite sufficient to complete the circuit. But how are we to explain this seeming anomaly? The fact is, that the current, though small in quantity, is of that precise intensity that it will pursue, without deviation, the path of a good conductor, when such is offered for its transit; and when no such medium is present, it is sufficiently powerful to force its way without difficulty through the substance of imperfect conductors: hence the integrity of the current along the line-wire, and the ease with which it returns by the earth."

## THE IMPROVED ENGINE COUNTER,

Exhibited by Mr. John Richmond, Middlesex, (Class V., No. 775,) is also applicable to turnsilles of bridges. By this counter, the number of strokes made by the engine can be read at once without calculation. The large unit-hand traverses the entire circumference of the dial, and the three small hands revolve in the same direction. The first motion being given by a sliding-bar and fixed spring, the first wheel can only be thrown 1 tooth by each stroke of the engine. The hands move by a series of wheels and pinions; no skip wheel being employed, the motion is regular and progressive.




The large circle dial, fig. 1, contains 100 divisions, and is traversed by the large hand at the rate of one division each stroke. Fig. 2 dial contains 100 divisions, each being equivalent to a complete revolution of the hand on fig. 1, thus registering 10,000 strokes. Fig. 3 dial is divided in the same way, registering 100,000 strokes; and fig. 4 dial is divided into 100 parts, registering 1,000,000. In this manner any amount can be read off with perfect accuracy.

## NATURAL PHILOSOPHY AND CHEMISTRY.

### CHAPTER XIII.

#### DIATHERMANCY.

There is no experiment better known than that of concentrating the solar rays by means of a convex lens—popularly denominated a *burning-glass,* in allusion to the effect produced. This experiment, besides demonstrating the high intensity of the celestial radiation, proves to us that heat like light is susceptible of refraction, and like it, traverses space in radial straight lines. We, moreover, know that these properties are independent of the light with which the heat is in this case associated ; for we have already seen (chap. x. p. 325), that by subjecting the solar-beam to prismatic refraction, the heat, which is the least refrangible element, can be separated almost, if not entirely, from the luminous rays of the spectrum.

There is, however, a much simpler mode of showing the physical independence of solar light and heat than by prismatic refraction. Thus, if we form a lens of alum and green glass, coloured by oxide of copper, we shall obtain at its focus, in the same manner as with a lens of common glass, a bright image of the sun; but without the slightest appreciable heating power. This experiment may readily be made by transmitting the solar light through a compound plate of the substances named, and afterwards concentrating it by a powerful glass lens upon the bulb of a delicate thermometer.

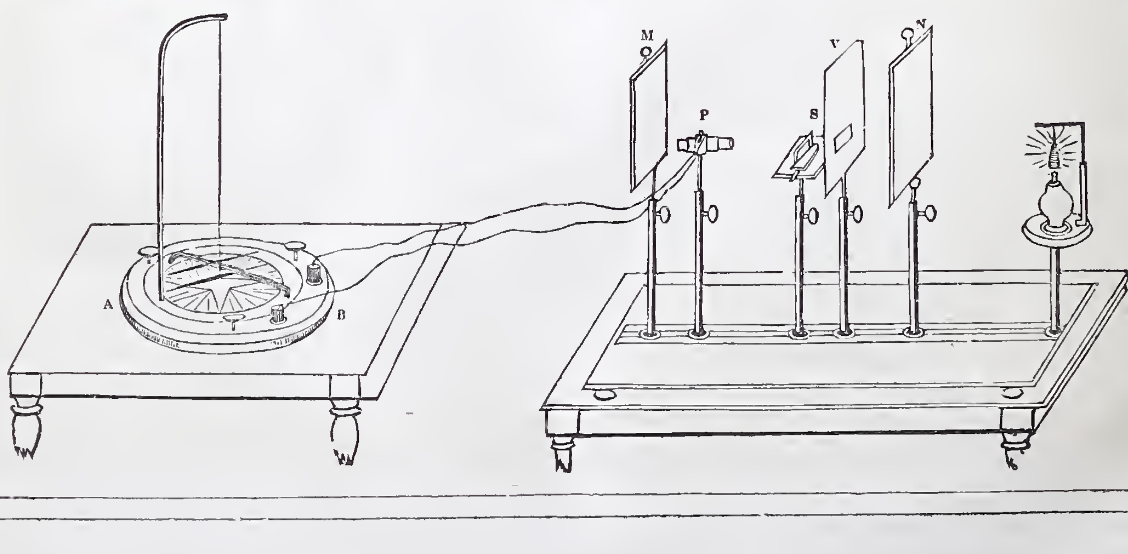
The question occurs—what becomes of the heat thus stopped in its progress? The answer is, however, very manifest, especially when it is found that the temperature of the plate is raised during the experiment above that of the surrounding atmosphere—a fact which may invariably be observed, and which can only be explained upon the principle that the heat, being free and independent, is arrested in its progress, and absorbed by the substance of the plate at the same time that the light is freely transmitted.

But, in entering upon the discussion of the effect of bodies upon heat traversing their substances, it is necessary to distinguish the source, and examine more closely the intimate nature of heat. In these experiments, we have referred only to the heat which comes to us from the sun; and for heat emanating from that source, the results are uniform. But when we employ heat obtained from a terrestrial source, we discover that the phenomena not only differ from those which result from the transmission of celestial heat, but differ among themselves to an extent which at first seems to preclude all classification. Thus, while glass arrests scarcely any portion of the direct solar heat, the thinnest plate of it interposed between us and an intense fire, acts as an effectual screen This fact affords to the glass-maker a convenient mode of protecting the eyes, when it is necessary to inspect the interior of his glowing furnace. It is not however correct to say that none of the heat from such a source is transmitted by the glass. This was till lately the received opinion, and that glass screens were as effectual as opaque ones in arresting the heat of a fire ; but it is now ascertained that a variable portion of terrestrial heat, depending upon the temperature and nature of the radiating body, does pass through. Thus, it was observed by Delaroche, that a glass screen transmitted $\frac{1}{40}$ of all the heat which fell upon its surface from a body heated to 182° ; when the temperature of the body was raised to 346°, as much as $\frac{1}{16}$th passed through ; and when raised to 960°, so large a portion as $\frac{1}{4}$th was transmitted. The fact is, however, more strikingly illustrated by the flame which is obtained by the combustion of a mixture of oxygen and hydrogen gases. In this flame, we have the greatest heat which art can command, although accompanied by very little light. If a convex lens be held before it, the heat transmitted through the glass, even when thus concentrated, can scarcely be appreciated by the most delicate air-thermometer. But if a piece of lime be placed in the flame, where it undergoes no chemical change, but emits a light which in point of intensity almost rivals that of the meridian sun, radiation of heat immediately takes place, and at the same time is projected of sufficient intensity to permeate the lens, and inflame a piece of phosphorus placed in its focus.

This experiment, besides, goes far to show that solid matter is essentially necessary to the propagation both of light and heat.

The subject of the transmission of heat through various media has of late been investigated by M. Melloni and Professor Forbes, with great success. Modern science has placed at their disposal a means of measuring temperature, infinitely more sensible than any form of thermometer formerly in use, and enabled them to conduct experiments with facility and accuracy which could not have been undertaken by the older philosophers. The apparatus to which we refer are the *galvanometer* and *thermo-multiplier.* The first of these instruments has long been known in some one or other of its forms ; but the latter is the invention of M. Melloni, to whose admirable memoirs, in which he has recorded his experiments and deductions, we are indebted for the greater part of what we yet know of this branch of thermotics.

These instruments will be described very fully when we come to treat of galvanic apparatus; but in the mean time, we may observe, that the thermo-multiplier consists of an arrangement of thirty pairs of antimony and bismuth bars, placed in a brass cylinder P, and having the wires from its poles connected with a very delicate galvanometer A B. The extremities of the bars being exposed to any source of radiant heat, as that from a coil of platinum heated by a spirit-lamp, while the temperature of the other extremities of the bars



are not altered, a current of electricity, proportional to the quantity of heat falling upon the exposed extremities of the bars passes through the wires from the poles of the pile, and causes the magnetic needle of the galvanometer to deflect more or less, according to the quantity of electricity circulating. In a little frame, s, is placed the substance whose action upon the rays of heat is to be tried; this is situated immediately behind a screen, v, having an aperture in it somewhat smaller than the plate through which the heat is to be transmitted. Sometimes other precautionary screens as M, are employed to protect the pile from irregular radiation, and other disturbing causes, on the end next the galvanometer, and, as it is important that the action of the heat upon the bars be limited to the actual time of the experiment, the double screen N is interposed immediately between the transmitting screen v, and the lamp, so that, being provided with a hinge, it may be raised or lowered whenever the rays of heat from any source are to be allowed to pass, or are to be intercepted.

It is obvious, from this arrangement, that no heat from the radiating body can reach the pile, except through the substance placed behind the aperture in the screen v.

In experiments with this apparatus, it appears that the power of bodies to transmit radiant heat is totally independent of their power to transmit light;—in other words, bodies are not *transparent to heat* in the same proportion that they are transparent to light. Among crystallized bodies in particular, it is found, that some which are highly transparent, intercept nearly the whole of the calorific rays, while others act directly contrary. These properties are observable, whatever may be the temperature of the source, but they become still more remarkable at very low temperatures. This is very obvious from the following table, where the plates of the substances named are understood to have a common thickness of a tenth of an inch (accurately 0·1031 inch), and that the source of heat is an argand oil-lamp. Of 100 incident rays there passes through

| | | |
|---|---|---|
| Rock-salt, | colourless, | 92 rays. |
| Calc-spar, | do. | 62 |
| Smoked topaz, | brown, | 57 |
| Carbonate of lead, | colourless, | 52 |
| Plate-glass, | do. | 40 |
| White agate, | do. | 35 |
| Glass (coloured), | violet, | 34 |
| Do. do. | red, | 33 |
| Sulphate of baryta, | colourless, | 33 |
| Chromate of potash, | orange, | 33 |
| Borax, | colourless, | 28 |
| Glass (coloured), | green, | 23 |
| Do. do. | yellow, | 22 |
| Do. do. | blue, | 21 |
| Sulphuric ether, | colourless, | 21 |
| Gypsum, | do. | 20 |
| Tourmaline, | green, | 18 |
| Opaque glass, | black, | 16 |
| Fluor spar, | colourless, | 15 |
| Citric acid, | do. | 15 |
| Alcohol, | do. | 15 |
| Alum, | do. | 12 |
| Water, | do. | 11 |
| Sulphate of copper, | blue, | 0 |

It thus appears that rock-salt has the greatest *diathermancy*, and that of all colourless transparent bodies, water is the least *diathermanous*. Colourless mirror glass arrests more than one half of the heat which it receives, while transparent alum allows less heat to pass through it than the deepest coloured glasses. With the exception, however, of the black glass, all diathermanous bodies, as far as is yet known, belong to the class of transparent bodies: metals, stones and wood, which totally obstruct the passage of light, obstruct that of heat also. It will, however, be observed, that sulphate of copper, which is of a blue colour, and strongly diaphanous, is perfectly *athermanous*.

But not merely do different bodies act differently on rays of heat proceeding from the same source, but the same substance may allow the heat of one source very free passage through it, while it intercepts partially, or completely, the heat radiated from another. Thus, of the heat radiated from the four sources named in the following table, the quantities transmitted vary in a very remarkable manner, and differ, with one exception, very sensibly from the results shown in the table above, where the source is an argand lamp. The figures denote the quantities per cent of transmission:—

| Substances, common thickness $\frac{1}{10}$ inch. | Locatelli Lamp. | Red-hot platinum. | Copper at 734° F. | Copper at 212° F. |
|---|---|---|---|---|
| Rock-salt, | 92 | 92 | 92 | 92 |
| Fluor spar, | 78 | 69 | 42 | 33 |
| Iceland spar, | 39 | 28 | 6 | 0 |
| Mirror glass, | 39 | 24 | 6 | 0 |
| Pure rock-crystal, | 38 | 28 | 6 | 0 |
| Agate, | 23 | 11 | 2 | 0 |
| Gypsum, | 14 | 5 | 0 | 0 |
| Citric acid, | 11 | 2 | 0 | 0 |
| Alum, | 9 | 2 | 0 | 0 |
| Pure ice, | 6 | 0 | 0 | 0 |

It thus appears that rock-salt is not only the most diathermanous substance known, but it is further remarkable as the only body which transmits the same amount of incident heat from *all* sources. The diathermancy of every other substance varies, under the same circumstances, with the temperature of the radiating source—the diathermancy increasing with the increase of temperature.

It may also be observed in relation to this remarkable difference in the power of transmissibility, that it not only differs according to the temperature at which radiation takes place; it differs likewise according as the plate is more or less attenuated. This leads to the conclusion, that the calorific rays are intercepted in the very interior of the plate, and in virtue of an absorbing force, similar to that which extinguishes certain portions of light in coloured media. The obstruction is not however in proportion to the thickness. On the other hand, the action of these media upon radiant heat, seems not to consist in merely stopping a certain portion of it, but in separating it into two portions, physically distinct, of which one finds free transmission, while the other is absorbed. Hence of two plates of the same substance, the second allows a large portion of that heat which has been transmitted by the first to pass through it. Thus, a plate of alum which intercepts 91 per cent. of the direct rays of a lamp will transmit 90 per cent. of rays which have already passed through a plate of the same substance; and Iceland spar which intercepts 61 of every 100 direct rays, transmits 91 per cent. of those which have passed through alum, and 89 per cent. of those transmitted by gypsum. On the other hand, it has been found that green tourmaline which transmits only 18 out of 100 rays directly incident upon it, intercepts 99 per cent. of those which had previously passed through alum, but gave passage to $\frac{3}{10}$ of the radiant heat transmitted by black glass. Alum again intercepts all the heat transmitted by green glass.

It may also be remarked in connexion with the greater power of transmissibility as the temperature of the source increases, that this discovery is important in so far as it establishes a relation between solar and terrestrial heat. It indeed leads to a very remarkable conclusion; for while glass intercepts 100 per cent. (the whole) of the heat radiated from a source of 212°, 94 per cent. of that from a source at 734°, 72 from incandescent platinum, 61 from Locatelli's lamp, and arrests scarcely any perceptible portion of the direct solar heat, we are irresistibly led to regard the actual temperature of the sun as far exceeding that of any temperature which we can command. It may be even further observed, in connexion with the different radiating powers of the pure oxy-hydrogen flame, and that of a lime-ball ignited by the same flame, and forming the well-known Drummond light, that this

fact goes far to disprove the astronomical hypothesis, that we owe the light and heat of the sun to a luminous atmosphere, and to bring us back to the older notion, that the material mass of the sun is itself in a state of intense incandescence.

The transmitting power of rock-salt being constant for all kinds of heat, that is, heat of all temperatures, it is easy to see that it must be of great importance in carrying on investigations relative to the nature of radiant heat. Lenses formed of it are true burning glasses; for they are capable by their refractive power of concentrating the feeblest rays to a focus, in the same manner as glass lenses concentrate luminous rays which are made to pass through them. By this means we are able to obtain very decided indications of heat emanating from a vessel of tepid water placed at a short distance, or even from the hand. A prism formed of the same substance is even more useful; for, from this we learn that the physical distinction between intercepted and transmitted portions of heat is to be found in the different refrangibility of the rays of heat radiating from sources of different temperatures; being to heat what colourless glass is to white light, it allows rays of all degrees of refrangibility to pass through its substance, furnishing us with a calorific spectrum, which, compared with the luminous spectrum, shows that the mean refrangible of heat is less than that of white light. Thus the most refrangible calorific rays fall no higher than the middle of the luminous spectrum, whilst the least refrangible fall considerably below the limits of the least refrangible (red) rays of light. The light transmitted by alum is by this means shown to be the very least refrangible rays, and that glass and gypsum give passage to the rays of least and mean refrangibility. The former may thus be compared in its action upon heat to ruby-red glass in reference to light; while glass and other bodies which transmit rays of least and mean refrangibility, may be supposed to resemble orange-coloured glasses, which intercept the blue and violet rays of light, but transmit the red and yellow. On the other hand, a plate of rock-salt when smoked, becomes to heat what blue glass is to light—it excludes the rays of least refrangibility; and when such a plate is combined with a plate of alum, all the incident heat is intercepted precisely as a double plate, composed of blue and orange glasses, producing perfect opacity, the one absorbing the portion of light which alone the other is capable of transmitting.

Among the calorific rays emanated from terrestrial sources of various temperatures, there are some which have a resemblance to the solar heat, and among the sun's calorific rays, some are again found similar in every respect to the calorific rays of flame. Thus the small quantity of heat which emerges from alum, passes freely through glass—and indeed all diaphanous colourless plates—and suffers no appreciable loss when the thickness of the plates is varied within certain limits. With regard to transmissibility, these rays then bear a close resemblance to those of solar heat, and they bear an equally close resemblance in the decided influence which colour has upon their absorption.

It is thus manifest, in respect to the phenomena of transmission, that the physical difference recognised between solar and terrestrial heat is to be found in their different degrees of refrangibility, and it is now very fully established, that the higher the temperature of the source, the more does the radiation resemble red light; and the lower the source, the greater analogy does it bear to the violet rays of the chromatic spectrum. Hence, by referring back to the last table, we observe that alum intercepts all the heat from a source of less intensity than incandescent platinum, and the few rays which it transmits of the radiated heat of this source, are strictly analagous to the less refrangible calorific rays of the sunbeam. On the other hand, glass gives passage to calorific rays of mean and of least refrangibility, and hence transmits all incident solar heat, of which no portion seems to be of so high refrangibility as the least refrangible rays which emanate from terrestrial sources of lower temperatures than 600°.

M. Meloni has further remarked, that the heat of one source may change its degree of refrangibility, and thereby take the specific character of heat emitted from a different source. Thus, the solar rays, deprived of all their more refrangible heat by passage through a plate of alum, may be received upon a blackened surface, the temperature of which will in consequence be elevated and converted in turn into a source of radiant heat; but if we examine the character of the calorific rays which it emits, we find that they are totally changed, and will no longer pass through alum; and transmitted through a prism of rock salt, we perceive that they have passed from a state of heat of the lowest, to heat of the highest degree of refrangibility. In like manner, if the most refrangible rays emanating from a source at 212°, be concentrated by a rock-salt lens, and brought to act on a very small surface, they may raise that surface to a temperature considerably above 212°, and be radiated from it in a less refrangible condition than before.

This conversion of heat of one specific character into that of another, is very beautifully exemplified upon the great scale of natural phenomena. Thus, it has long been observed, that pure snow and ice are comparatively little affected by the direct solar radiation, but melt rapidly around the trunks of trees, among shrubs, and other dark-coloured objects, upon which the sun shines. This was at one time accounted for on the supposition that vegetable bodies possessed a certain amount of internal heat, which they radiated abundantly under circumstances of this nature; but this hypothesis is set aside by the fact, that the thawing influence is at least equally strong around dead bushes and dry poles, as it is in the vicinity of live vegetation. It seems, moreover, to be greatly influenced by the number of branches, the smallness of the twigs, and their depth of colour. The effect, besides, is uniformly observed (in this country) to commence on the south side of such objects, and to extend gradually by the west, till it reaches round to the north; it, in fact, follows the path of the sun, and is obviously the result of secondary radiation. In other words, the heat of the sun being received and absorbed by the deep-coloured and opaque objects, these become sources of radiation; but the heat which they radiate is changed from a state of low refrangibility to a state of great refrangibility. In the former state, ice and snow transmit it freely through their substance. In the latter state they absorb it completely, and are melted in consequence.

This different effect of the rays of heat from different sources upon snow, may be shown by a still more direct experiment. Let a differential thermoscope be put between an argand lamp and a blackened copper surface, heated by a spirit lamp to 752°, so as to be in equilibrio between them, which may be effected by approaching the instrument nearer to the feebler source of heat than to the other. Having ascertained the position of equilibrium, let the thermoscope be removed, and a tube, divided into two by a diaphragm, and filled at each end with newly-fallen snow, be exactly placed in its position, with one face presented to each of the calorific sources. Notwithstanding the equality of the intensity of the heat, as measured by the thermoscope in this position, the snow in the tube, opposed to the heated copper, will melt much faster than in the other; it will, indeed, generally disappear in half the time. The experiment may be made still more simply, by suspending over a surface of snow, and close to it, a disc of tinfoil, covered on both sides with lamp-black. If the rays of an argand lamp be made to fall upon it, the surrounding snow will be only slightly affected, but a cavity will quickly be thawed under the disc. If the heated copper be now substituted for the lamp, the phenomena will take place in the inverse order; the melting of the snow will be more abundant in the parts exposed to the direct radiation than under the disc, so that, in a short time, a protuberance is observed in the latter situation, instead of an excavation.

These experiments directly show that heat is more absorbable when it is radiated from sources of low, than from sources of high temperature. Thus the heated disc emits rays more absorbable than the direct rays of the lamp, and hence the snow is melted in greater abundance under the

shadow of the disc than elsewhere, notwithstanding that the heat is less. In the case where the copper is used as the radiating body, the refrangibility of the rays is the same, but the disc, by its interposition, diminishes the effect of the direct radiation, and protects the snow in the part which it screens. In the same way we might perhaps account for the influence of colour on the power of bodies to absorb the heat of the sun. For instance, the well known experiment of spreading stripes of cloth of different colours on the surface of snow during sunshine, and in which it is found that they descend in proportion to their depth of colour, might be explained on the principle that their colours give them the power of changing heat, which would be transmitted, into heat which would be absorbed by the snow on which they rest, in proportion to the depth of these colours.

From the experiments described above, and others which might be enumerated, it would appear that the distinction between solar and terrestrial heat is one simply of degree, and is by no means absolute, as was but lately supposed. Thus, although colour has no appreciable influence upon the absorption of those species of heat which are unaccompanied by light, its influence is very decided when the temperature of the source is very high and luminous. This influence may indeed be calculated; for if we suppose with M. Melloni, that those rays from common sources which pass through glass possess the same properties as solar heat, we are able to ascertain the effect of colour upon the whole incident heat of such a source. The ratio which the amount of rays transmitted by glass bears to the amount absorbed, may, indeed, in cases of terrestrial heat, be reckoned in some degree a measure of the approach which the intensity of the radiation makes to that of the celestial luminary. Thus, if we have a transmission of 40 per cent of the heat incident upon a thickness of glass which transmits all the calorific solar rays, we may conclude that the intensity of the radiation of that source is to the intensity of the solar radiation as 2 is to 5. In this, however, there is no reference to *quantity*.

It is scarcely possible to close these remarks without alluding summarily to the analogies recognised between the phenomena of heat and light. That these agencies are physically independent of each other, is clearly shown by the fact that they may be entirely separated even when they come to us in the form of a sunbeam. That they are intimately related, is, however, shown by their obeying the same laws of refraction. Heat, it is true, is less refrangible than light, but it still obeys the law of sines; and being incident upon a doubly refracting substance, the rays after emergence are found like those of light, to be polarized in planes perpendicular to each other; leaving no doubt that were our organs and our instruments of a construction suitable for their appreciation, all the corresponding phenomena to those of colours in the case of light might be obtained and made sensible. The phenomena of interference have not however been yet observed; but although we have not up to the present time recognised the actual production of cold by the combined action of two rays of heat, the analogy in other respects is so close that it seems probable in this case that additional observation alone is wanting. Moser's hypothesis of latent light, (p. 79) may perhaps be placed in juxta-position with Black's theory of latent heat; for although additional investigation be still required to place it on the same firm basis, the evidence already adduced is of a kind not to be lightly estimated. In the conversion of calorific rays of one degree of refrangibility into those of other degrees, we, however, recognise a case to which the phenomena of light furnish no parallel; for we have never known red light converted into blue, or violet into orange.

We have no wish here to enter upon a formal discussion of the unanswerable question—*What is heat?* It may, however, be observed in reference to the subject, that all the phenomena of its absorption by bodies suggest to us the idea of a substantial existence; for, under these circumstances, it is never extinguished, but is accummulated in the body, and may again be derived from it without loss. But again, were we to adopt this material hypothesis, it would at the same time be necessary to assume that there are as many different kinds of heat, as there are different degrees of refrangibility observed; and, to increase the difficulty, it would be necessay further to assume that the material atoms, of which these different species of calorific rays are made up, may have their properties altered at pleasure by secondary radiation. On the other hand, if we adopt the undulatory hypothesis as explained in the case of light, a difficulty occurs in the explanation of accumulation, and of specific and latent heat; but we find an easy explanation for the conversion of one species of heat into heat of another kind. Thus conceiving radiant heat to consist in vibrations of the same ethereal medium which produces light, and assuming, as in the case of light, that difference of refrangibility depends upon a difference in the length of the undulations—the red rays being due to the longest, and the violet to the shortest waves—we readily infer, that the different properties of heat, evinced by different degrees of refrangibility, are in like manner referrible to the differences in the sizes of the calorific waves. This hypothesis is, moreover, more consonant to our ideas of the harmony and simplicity of nature; for, if the whole phenomena of colour can be rendered sensible in a medium pervading space, by undulations so narrow, that the longest (red) is to the shortest (violet) as 38 to 60, it coincides with our conceptions of the various and beautiful adaptations manifested in nature, to suppose that the same medium is subservient by another range of lengths—greater than those of light—to the transmission of radiant heat. Upon this hypothesis, we obtain by a third order of vibration, in the same medium, still shorter and more refrangible than those of violet light, a body of rays, which from their capability of acting upon the elementary constituents of bodies, are called *chemical rays*. We do not enter upon a discussion of the properties of these rays at present; but, simply noticing their existence, we cannot resist the conviction that the union of three orders of rays in the solar light offers a very strong argument in favour of this view of the subject; "for we can well imagine, that by whatever means the sun communicates to the ethereal expanse the vibrations of various lengths which constitute the rays of light, that vibrations of other magnitudes, greater or less, should be at the same time produced, and thus the light which exhibits to us the beauty of the external world, be accompanied by heating power, which animates all living nature, and without which, the universe should be a tenantless and barren void."

A theory of heat, however, will in all probability require still many years of patient research for its construction. Even adopting the undulatory hypothesis for its radiant form, there are difficulties involved, which even at this advanced stage of physical inquiry, can hardly be reduced to limits sufficiently precise for examination. Taking conduction as a case of radiation, there still remains to be included in any explanation which may be made the basis of a rational theory, the connexion between specific and latent heat, and what seems still more difficult, between heat in its states of freedom and combination. The laws which regulate the expansion of bodies, and by which heat acts in opposing the cohesive force by which the elements of bodies are bound together, must be comprehended within the folds of the same principle. Even the unlimited heat obtainable by the friction of hard bodies, still wants a satisfactory explanation, and it can hardly be said that we have made one step in assigning a cause for its evolution in electric action. There remains therefore ample scope for research in this interesting though recondite department of physical science; and although many experimenters are already in the field, whose labours are continually eliciting new and important facts, it is not difficult to perceive, that the speculations as yet brought forward respecting the ultimate nature of heat are too vague and indefinite, and moreover, too circumscribed, to be taken as a physical theory. A principle of a higher order than any hypothesis hitherto offered, seems still to be wanting; a principle of so general a kind, that the thermotics and optics of the present day shall fall within it as particular cases.

# MECHANICS.

## PART II.—ELEMENTS OF MACHINERY.

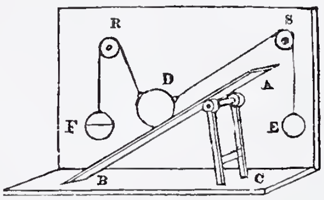
### CHAPTER IV.

#### THE INCLINED PLANE.

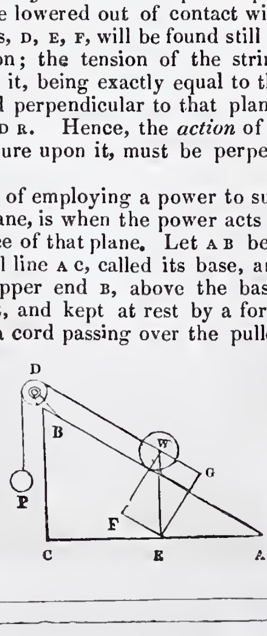
The inclined plane is the representative of the second class of mechanical elements. Its fundamental law of action is that of the composition and resolution of forces. The manner in which the advantage is immediately derived from it, is therefore distinct from that of the first class. In that class, there is necessarily a fulcrum, a point round which all the motion takes place, and through which the power acts on the resistance; whereas in this class, there is no apparent centre of action.

When a body is lying at rest on a smooth horizontal surface, it exerts a pressure on that surface perpendicular to it, which is resisted by a pressure equal and opposite from that surface. For this reason the body remains at rest; and in fact when any surface is acted upon by a force, in any given direction, the resistance of the surface is always in a direction perpendicular to itself. Now, a plane smooth surface, which forms an angle with the horizon, is an *inclined plane*, and is therefore incapable of supporting by itself any weight laid upon it. This may be shown by a very simple experiment.

Take a plane board A B, and prop it up at one end A, by the support A C, which may be hinged to it at A, so that by drawing the lower end C in or out, different inclinations may be given to the board. Place a body D upon the plane surface, and keep it at rest by the cord D S, which is in the direction of the plane, and which is passed over a pulley, S, with a proper weight E, at the end of it. Now, the force of D is in the direction of gravity, and will therefore be resolved into two other forces, one parallel to the plane, showing the resistance overcome by the weight E, and the other perpendicular to the plane, showing the amount of pressure upon it. Let, therefore, another cord be fastened to the weight D, and carried up perpendicular to the plane over a pulley R. Into a small pan F, at the end of the cord, place small weights successively, until D *just* ceases to press upon A B. Then if the plane A B be lowered out of contact with the weight D, the three weights, D, E, F, will be found still to remain in their former position; the tension of the string D R, or the force acting upon it, being exactly equal to the *reaction* of the plane A B, and perpendicular to that plane, or in the direction of the line D R. Hence, the *action* of D, upon the plane A B, or its pressure upon it, must be perpendicular to that plane.




The most advantageous way of employing a power to sustain a weight on an inclined plane, is when the power acts in a direction parallel to the surface of that plane. Let A B be a plane inclined to the horizontal line A C, called its base, and let B C be its height at the upper end B, above the base. Let W be a body lying upon it, and kept at rest by a force P, acting upon it by means of a cord passing over the pulley D, at the top of the plane, the part D W being parallel to the plane. Now, draw a perpendicular line W E, to represent in direction and magnitude the force of W, acted upon by gravity. Then the force W E, being exerted obliquely upon the plane A B, we must, in order to determine the amount of pressure upon it, draw W F perpendicular to the plane, and E F parallel to it, and finish the parallelogram by drawing E G and W G; then W E is equivalent to W F and E F or W G. Thus, W F is made to represent the direction and magnitude of the pressure of the weight upon the plane, and E F, or W G, the force or tendency of the weight down the plane, which remains to be balanced by the force P, as it is parallel to the plane, and is equal and opposite to the force P required to keep the weight W at rest.




The triangle W E F, will therefore represent by its three sides W E, W F, and F E respectively, the weight of the body W, the perpendicular pressure of that weight on the plane A B, and its force in the direction of that plane, which, as it cannot be opposed by the plane itself, remains to be balanced by the equal and opposite force P. Now, the triangles W E F and A B C are exactly similar, so that their sides respectively have the same proportion to one another. In this way, W E : E F : : A B : B C; and thus as W E represents the weight of W, and E F its tendency down the plane, which is equal to the force P; and, moreover, as A B is the length of the plane, and B C its height, the above proportion signifies the following general principle, namely, that a weight resting on an inclined plane is to the power required to keep it at rest, when acting parallel to the plane, as the length of the plane is to its height.

For example, if the length of the plane be 24 feet, and its height two feet, and supposing W a weight of 120 lbs., then the force P necessary to retain it at rest is 10 lbs., according to the proportion,

24 : 2 : : W : P : : 120 lbs. : 10 lbs.

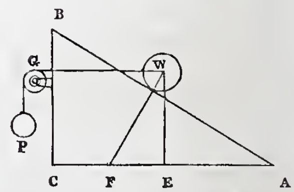
The mode of finding P is as follows: multiply the weight to be raised by the height of the plane, and divide the product by the length of the plane; the quotient found is the power Thus in the preceding example, 120 lb. $\times$ 2 $=$ 240 lb., and 240 lbs. $\div$ 24 $=$ 10 lbs.

But again, from the similarity of the triangles before observed W E : W F : : A B : A C, showing that the weight of W is to its perpendicular pressure upon the inclined plane, in the proportion of the length of the plane to its base.

In general, therefore, the sides of the triangle formed by an inclined plane, its base, and its height, are respectively proportional to a weight at rest upon it, the pressure of that weight upon the plane, and the power necessary when acting parallel to it, to maintain the weight at rest.

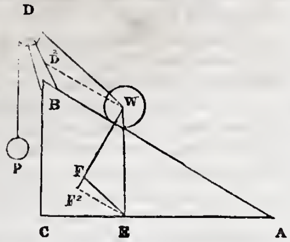
A similar process enables us to ascertain the power necessary to keep the weight at rest on an inclined plane, when the power acts in a direction parallel to the base.

Let the force P act on the body in the direction W G, parallel to the base A C. Draw W E perpendicular to A C, representing the weight in magnitude and direction; and W F perpendicular to A B, meeting A C in F. Then, in the triangle W E F, W E is equivalent to W F and E F, of which W F shows the pressure on the plane A B, and E F, the power in the direction W G, sufficient to retain the body at rest. Now, the triangle W E F, is similar to A B C, so that W E : E F : : A C : B C, which signifies in words that the weight is to the power, as the base to the height of the plane. Now, when the power acts parallel to the plane, as has just been shown, the weight is to the power as the length to the height of the plane. A given power, therefore, will support a greater weight in the latter case, than in the former, inasmuch as the length of the plane is greater than its base. Therefore, also, a less power will support the same weight in the latter, than in the former case, showing that the power acts more advantageously when applied parallel to the plane. Again, W E : W F : : A C : A B, that is, the weight of W is to its pressure on the plane A B, as the base is to the length of the plane, showing that the pressure on the plane is greater than the weight of W itself, whereas, in the other case, it is less. These disadvantages hold, in every case in which the power is applied,



in a direction below that of the plane itself, diminishing however, as it approaches the direction of the plane.

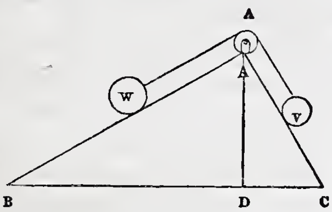
Further, if the power be applied in any direction above that of the plane, the pressure of the weight on the plane is less than the weight itself, but, at the same time, as in the other extreme case, the power required to balance the weight is also greater than is necessary when it acts in a direction parallel to the plane, as it tends to raise the weight off it.




Let the weight W be kept at rest on the plane A B, by the force P acting on W, in the direction W D, at an angle with A B, receding from it towards D. Draw W E perpendicular to A C, representing the weight of W; draw W F perpendicular to A B, and E F parallel to W D, then is W E equivalent to W F and F E; of these, W F represents the pressure of the weight on the plane, and E F is the force acting on the string W D, which is counteracted by the power P.

Had the power been applied in the direction W $D_2$, parallel to A B, then we would have drawn E $F_2$ also parallel to A B, or perpendicular to W $F_2$. In this case, W $F_2$ would have been the pressure upon the plane, and E $F_2$ the power required. Now W F is evidently less than W $F_2$, that is, the pressure on the plane is less in the first case than in the second, which is explained on considering that, on the other hand, E F is greater than E $F_2$, that is, the power required to keep W at rest, when acting in a direction rising above the plane, is greater than what is necessary when it acts in a direction parallel to it.

From what has been said, it appears that of a series of inclined planes, having the same altitude or height, the longer they are, the less power is requisite to balance a given weight laid upon them. Let there be two planes A B, A C, of different degrees of inclination, but of the same height A D, joined at that line; and, also, suppose two weights, W V, upon these planes respectively, balancing one another over the pulley at A. In this case, then, the force exerted by each of them on the string, or the power necessary to maintain them at rest, must be the same.




Now, this power is to W, in the proportion of A D to A B, and it is also to V, as A D to A C; showing that these weights are in the proportion of the lengths of the planes on which they lie, that is,

W : V : : A B : A C.

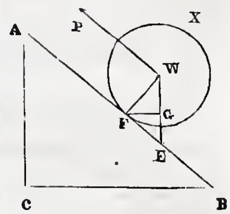
Therefore, if A B, be 12 inches, and A C, 6 inches; and if W be 10 lbs., then V must be 5 lbs.

This property of the compound inclined plane was first pointed out by Simon Stevin, a Flemish mathematician of Bruges. His simple and ingenious method of proof was, by supposing a uniform endless chain hung over the double plane, and hanging in a curve below the points B, C, in the last figure. He argued that, as the chain, in this condition, remains at rest, if the part below the points B C be taken away, the remaining parts lying along A B and A C will continue to be at rest, since the hanging part acted with equal force upon the points B C; and, of course, if these two equal and opposite forces were removed from the parts on A B, A C, the equilibrium of these portions of chain remains unaffected. Now, the weights of these parts must be in proportion to the lengths of the planes A B, A C. And substituting single weights for the chains, they still balance one another; being in the proportion of the lengths of the planes on which they rest.

The preceding propositions on the inclined plane do not take into account the effects of the friction of the surfaces in contact. For cylindrical bodies, the allowance for friction is trifling, as they roll on the plane. But for flat bodies which rub, it is considerable; and, that the power may be best applied, its direction should not be parallel to the plane, but should form a certain angle with it, so as partly to relieve the friction.

Though the inclined plane is distinct from the lever in the mode of operation, inasmuch as there is no actual motion round a centre, yet, in another, and equally important sense, it is identifiable with the lever.

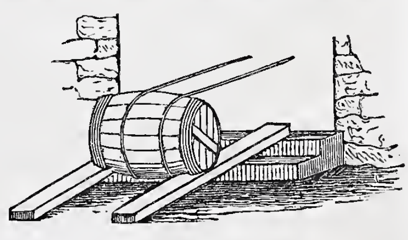
In the annexed figure, let W be a circular body, resting on the plane A B, of which A C is the height. Draw W P in the direction of the force applied, suppose, for simplicity, parallel to A B, and W E perpendicular to C B, representing the weight of W; and draw W F perpendicular to A B, and F G again perpendicular to W E. Now, the perpendicular W F must always meet the plane A B, at the same point F, at which the cylinder touches it. And again, the whole weight of the body may be considered to be gathered into the centre W, and to act in the vertical line W E.




As it matters not at what point in this line the force acts, suppose it, for the present, to act at G. Then F G is, in effect, one arm of a bent lever, of which F is the fulcrum, and the force at G is the weight or resistance; F W is the other arm, at the extremity W of which, the power P acts. Now, by what has been previously stated, W E represents the weight; it is equivalent to W F and F E, of which F E, parallel to W P, represents the power P.

The triangles W E F, and W F G, are similar to each other; so that W E : E F : : W F : F G and, by the rules of proportion, W E $\times$ F G = E F $\times$ W F. But W E $\times$ F G is the moment of the force W E in reference to the point F, and E F $\times$ W F is also the moment of the force E F, acting along W P, in reference to the same point F; and, as already said, W F G is virtually a bent lever, of which F is the fulcrum. Thus the conditions of equilibrium on an inclined plane are established on the principle of the lever. It may be observed, further, if F W be produced to X, and the power act at X, parallel to A B, it will evidently have its moment doubled, since F X is double F W. To balance, therefore, the same weight only one half the power is necessary. Strictly, then, the inclined plane ought equally with the pulley to be identified with the lever. In the lever there are three principal points: the fulcrum, and the two points of application of the forces. Now, the pulley is distinguished from the lever, because some two of these points are always changing when the pulley is in action. In the inclined plane, there is ultimately just the same ground for distinction and no more.

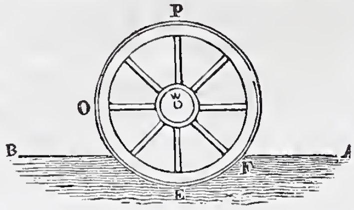
What has been just said explains the advantage of the method often employed of raising loaded hogsheads a few feet high into warehouses. Two planks being laid at the required inclination upon the steps, a rope is laid along each plank, passed under the hogshead, and returned over it into the warehouse.



The hogshead being advanced to the lower ends of the planks, manual power is applied at the ropes, by which it is raised to the floor of the store. If in this way two men are able to raise the hogshead, four men must be employed to raise it by simply pushing behind.

A case very similar to this happens when the wheels of a cart stick in the mud. In the annexed figure, a wheel is

shown imbedded to a depth A B; suppose the whole moving towards A; then E being the lowest point, and F where it meets the surface, the space E F is an inclined plane to be ascended before the cart can proceed. Now, the power of the horse is communicated through the trams to the centre W of the wheel, where it acts. But when men lend their aid, the most advantageous point at which their power can be applied, is at or near P. When applied at or near O, as is sometimes done, much power is wasted in simply raising the load, without a corresponding advantage. In pushing behind the cart, as the force is all communicated to the centre of the wheel, it is not so efficaciously expended as at P.




The inclined plane is much employed for raising great weights through small heights, generally higher than in cases for which the lever is used. Flights of steps are up-hill work made easy. The sagacity of horses drawing loads is displayed in the serpentine course they pursue when ascending steep roads. By this means, they in effect divide the road into a series of inclined planes of less steepness than the road itself. This has the disadvantage of increasing the length of the plane and the time of action, but reduces the force which would be necessary to do the work by going directly forward upon the steeper ascent.

## CHEMISTRY OF INORGANIC NATURE.

### CHAPTER IV.

#### THE EARTHS.

We have already disposed of three of the classical elements —fire, air, and water; and now proceed to examine the fourth, with a view to obtaining some preliminary acquaintance with the chemical properties of the solid materials which compose our globe.

In the first place, however, it is necessary to fix the popular meaning which we are to attach to the word Earth. And here some difficulty occurs, on account of the various significations which the word is made to bear. In astronomical language, it is used to denote the planet we inhabit, in contradistinction to the other planetary bodies of the solar system, which we designate by other appropriate names. In this sense, the term is rendered sufficiently precise by prefixing to it the definite particle *the*, which prevents all misconception. But when we speak of *an earth*, the meaning is left vague and indefinite, and can only be gathered from the general tenor of the words with which the term is associated. To arrive at a definition suitable for our purpose, it is, however, only necessary to reflect that the greater portion of the earth's crust is composed of rocks, of various degrees of hardness, closeness of texture, and aspect; and that these rocky materials are often found becoming disintegrated, and mouldering into small particles. The process of mouldering produces no change, further than breaking down the cohesion of the rock; for the loose powdery matter at the foot of the rocky mountain is found to contain precisely the same ingredients as the rocks from which it was produced. This debris constitutes *earth*, and in process of time, becoming mixed with organic matters, forms *soil*. But, as different rocks are composed of different materials, we are prepared to find that the earthy products which result from their disintegration differ also in the nature of their ingredients; and that, instead of one simple earth, we ought to find earths of different kinds, answering to the different sources whence they are derived.

It being thus understood that *earths* is simply the generic name under which are arranged the various ingredients of which rocks and stones are composed, we are placed in a position to study their nature, without reference to the diversified circumstances under which the substances lie scattered around us, and which seem, in their endless variety, to forbid all classification.

To acquire some preliminary acquaintance with these earths, previous to studying their properties more strictly, let us point them out individually as they occur in mineral Nature. It must, however, be observed, that we here rarely meet with any of them in a state of absolute purity;—when they are required in that state, we must have recourse often to very tedious and intricate processes.

Every one is acquainted with pipe-clay, and all have at least heard of the sapphire—a gem of various colours, and second, in point of value, only to the diamond. Now, these substances are very dissimilar, and both seem to differ essentially from common roofing slate; yet the sapphire is almost a pure specimen of that peculiar kind of earth which constitutes the chief ingredient of pipe-clay and roofing slate, and which indeed gives plasticity to all clays, whether existing in soil, or dug from the kaolin pit to form translucent china. From this extensive distribution in the form of clay, it acquired the name of *argillaceous earth*; but this name has been laid aside by chemists for the more systematic term *alumina*, by which it is now designated. It has obtained this name in consequence of its being the basis of alum, from which we can most easily procure it in a state of purity. To exhibit it in this state, it is only necessary to make two solutions—one of alum, and the other of potash,—and to pour the one solution into the other. We thus obtain a bulky white precipitate, which is alumina in a state very nearly pure. The pure white precipitate which we thus obtain presents no apparent analogy to oriental ruby (red sapphire), which we are warranted in reckoning the purest specimen of alumina which mineral Nature affords. The difference is not, however, of an essential kind. In the gem we find the earth crystallized, and deriving its beautiful and much-valued colour from a very minute admixture of iron—not more than one per cent.

Another very plentiful earth—one indeed which, like alumina, is abundantly diffused throughout Nature—is that which composes *flint*. The Latin name for this mineral is *silex*; and hence the earth of which it is constituted has obtained the name of *silica*. It is found in almost all solid mineral substances, and forms a large portion of the bulk of those rocks which compose the solid parts of our globe, and the sand which lies valueless on our shores. Among geologists, it takes the name of *quartz*, in its common crystalline state; and when these crystals are large, pure, and well defined, the mineral is popularly known as rock crystal. It is the main constituent of various gems. Amethyst, cat's-eye, onyx, and sardonyx, are all nearly pure silica, coloured by some metallic oxide; and the much-valued gem called precious opal consists of nothing more than nine parts of this earth, combined with one part of water. The stone called hydrophane is a more curious specimen of it. This stone is opaque till plunged into water, when it becomes one-half heavier, and transparent like glass.

Silica differs essentially from alumina, yet both are frequently found associated together in the same mineral. Thus, porcelain clay contains nearly equal parts of these earths; and, uniting with the oxides of iron, they form the reddle, or red ochre, of Staffordshire and Derbyshire. Fuller's earth, and the hard stone called agate, are also constituted of alumina and silica; and, together, they form the main part of all soils. In making earthenware, a due proportion of both these earths is requisite; for, were alumina alone used, the ware could not be sufficiently burned without shrinking too much, and even cracking; and a great excess of silica would lessen the tenacity, and render the ware brittle.

Silica is the chief ingredient in glass, and indeed of all vitreous substances. It is infusible alone; but, when intimately mixed with potash or soda, it may readily be fused; and if no other ingredient be added, the glass which is formed will have the property of being soluble in water. Flint glass

is rendered insoluble by admixture of oxide of lead, and crown and common window-glass by lime. Common bottle-glass differs from the first of these in containing no lead, and from the last in containing some iron, and from both in being formed of very impure materials—as common red sand and soap-boilers' waste ashes. Artificial gems, or *pastes*, are similarly formed, by fusing silica with soda, and adding some metallic oxide, to give the required colour.

It has been observed that silica and alumina are frequently associated together, often indeed forming gems of great beauty, as the garnet, the Brazilian topaz, and the precious emerald, of which the beryl is a species. These last are not, however, composed entirely of silica and alumina, but contain also another earth, to which chemists have given the name *glucina* (from a Greek word, *glukus*, sweet), on account of its property of forming, with other substances, combinations which have a sweet taste. It is, however, unlike the two earths with which it is associated in the emerald and beryl, a very scarce substance; it occurs, indeed, only in another very rare sub-species of the emerald, found in Peru and Brazil, and known to mineralogists under the name of *euclase*.

The gem called zircon (a species of the hyacinth), which is found in various countries, but especially in Ceylon, the great depository of all the richer gems, affords us another rare earth which has been named *zirconia*, in commemoration of the source whence it was first obtained. It is associated in zircon and hyacinth, with silica, and is distinguished from alumina and glucina by the character of the compounds which it forms with the acids.

Another of these scarce earths has been obtained from a Norwegian mineral named *thorite*. This is also a compound of silica with its new associate, which has been named *thorina*, after the mineral which affords it. Like those earths already noticed, it is white, but exceeds them all in weight, —its specific gravity being as much as 9·4, which is considerably greater than that of iron, 7·8, or even copper, 8·9.

Another distinct earth has been obtained from a rare stone found at Ytterby in Sweden, and hence called *yttria*. It resembles glucina in the property of forming combinations which have a sweetish taste; but most of them are distinguishable by a pale purple colour, and very readily by certain tests which we are hardly yet in a condition to describe.

We have now done with these rare specimens, and proceed to notice those better known and more important earths, which, with alumina and silica, constitute the great mass of the rocky materials of our globe. It was only necessary to mention the last four, in order to render our list complete.

Common experience has made most persons acquainted with marble. Its pure whiteness in some specimens, and its beautifully variegated hues in others, together with its high lustre when polished, have introduced it as an admirable material for sculpture and ornamental architecture. It is found of every variety and mixture of colour, from pure white to pure black. The purer specimens are highly valued; yet they are all nearly the same in chemical constitution, and differ in nothing except in their crystalline texture from common limestone and chalk—of which whole mountains exist in some parts of the world.

The earth of which limestone is composed, is never found pure in Nature, but is readily procured in that state by subjecting a piece of chalk to a white heat. The process of lime-burning has long been common in most parts of the world, with very little difference in the practical details. The stones are broken small and stratified with fuel in a kiln: this is set on fire, and heats the stone red-hot. During the burning, the stone becomes nearly one-half lighter, and its properties are totally changed. It is now quicklime. Formerly it might be placed in water without undergoing any change; but if water be now poured upon it, it is immediately absorbed, and the lime appears as dry as ever. In some time, however, it grows hot, swells, bursts, discharges steam, and falls to powder. This powder is called slaked lime, and weighs one-fourth more than the quicklime from which it was formed. Exactly the same phenomena are exhibited, whether the material used be common limestone, chalk, white, black, or variegated marble, transparent Iceland spar, oyster shells, or coral—all these are composed of the same substance, with a slight difference only in purity.

Quicklime is the earth of limestone—it is *lime*, properly so called. In transparent Iceland spar, which is pure crystallized limestone, it is found combined with carbonic acid (the gas which constitutes choke-damp), in the proportion of 28½ lime to 22 acid. Black marble is limestone combined with a small portion of bituminous matter. In gypsum and alabaster it is combined with sulphuric acid (vitriol,) and water. By burning gypsum to drive off the water in it, the substance forms plaster-of-Paris, so much employed in making casts. Animal bones are also mainly composed of lime in combination with phosphorus and carbonic acid. Combined with another substance called fluorine, lime constitutes Derbyshire spar—well known from the splendid ornamental vases and other articles which are formed of it.

Perhaps none of the earths are used for so many purposes in the arts as lime. In making mortar for building it is indispensable. For this purpose it is mixed with sand (silica), for which it has a great attraction, and without which the mortar never hardens. When the ingredients are mixed in the proper proportions, the lime gradually absorbs carbonic acid from the atmosphere; and this, in a series of years, passes again to the state of unburnt limestone. By the tanner, lime is used to dissolve the gelatinous part of the skin, and to facilitate the removal of the hair. In sugar-refining it is employed to free the sugar of an acid which prevents its crystallization; and by the soap-boiler to deprive his solutions of carbonic acid, which hinders the tallow and alkali from combining. The agriculturist uses lime extensively as a manure, and the manufacturing chemist combines it with chlorine to form bleaching-powder. In the manufacture of iron it is used as a flux, although it is alone infusible; and the apothecary dissolves it in water for medicinal purposes.

There are two minerals, very different from limestones, and from each other, and which are very commonly found associated with carbonic acid; but when burned, they afford earths which agree with lime in the property of swelling and becoming hot when cold water is poured upon them. Like lime, they undergo the processs of slaking. These minerals are named by chemists carbonate of baryta, and carbonate of strontia; and by mineralogists barolite, and strontites. From these names the earths are called baryta and strontia.

Carbonate of baryta was first discovered by Dr Withering of Birmingham, in the lead mines of Alston Moor, Cumberland, and at Anglesark, in Lancashire; but it is now found in other parts of England. The same earth is also found in even greater plenty in combination with sulphuric acid, forming heavy spar. In this state it is found very plentifully in the Derbyshire lead mines, where it is named *cauk* by the workmen; the island of Arran, in the Firth of Clyde; and at Muirshields, near Paisley. Manufacturers of white lead are blamed with being too well acquainted with it; when finely powdered, it is admirably adapted, on account of its great weight (which is one of its most characteristic properties, and that from which it has obtained its name,) to adulterate that article. It has also been used to give *body* to calicoes and paper for the purpose of deceiving the ignorant purchaser.

Baryta is distinguished amongst the other earths by being a violent poison. All its compounds also are poisonous, except the sulphate (heavy spar.) It yields the only white for water-painting that never changes; and it may be mixed with any other colour without injury. Various oil colours are now extensively manufactured from it by dyeing it the shade required. Almost all the Brunswick greens are thus obtained.

Baryta differs remarkably from lime in being very soluble in boiling water, from which it crystallizes on cooling. Lime, on the other hand, is but sparingly soluble in cold water, and can scarcely be said to be at all soluble in hot water.

Carbonate of strontia was first found in the lead mine of

Strontian in Argyleshire, but the sulphate is now found plentifully in several other places. Thus, near Bristol and Paris, it is employed as road metal, and in the state of Pennsylvania, United States of America, it occurs in great abundance. The earth which forms its base is not poisonous like baryta, but it resembles that earth in being very soluble in boiling water, and in crystallizing on cooling. Its distinguishing property is the red colour which it imparts to flame, and hence its use as an essential ingredient in the red fire of theatres. It has also been tried on a small scale in medicine.

The only remaining earth which we have now to notice in this summary, is that well known in popular medicine, under the name of *magnesia*. It exists in considerable plenty in mineral Nature—especially associated with lime in magnesian limestone. It is an ingredient of talc, soapstone, potstone, asbestos, fossil cork, and several other minerals generally of a fibrous texture and silky lustre. Epsom salt is a well-known combination of it with sulphuric acid; and from this salt the earth is usually prepared for chemical purposes. Separated from its combinations it is a very white, soft and light earth, does not slake like lime, and is almost insoluble in water. (According to Dr Fyfe, it requires 5000 parts of water for solution, whereas lime requires rather less than 800 parts of water at 50° F). It can easily be procured by subjecting the magnesia of the apothecary (which contains more than half its weight of carbonic acid) to a white heat; and this medicinal magnesia may again be procured by making a hot solution of Epsom salt and pouring into it a solution of carbonate of potash or soda: a double decomposition of the salt takes place, and the carbonate of magnesia which is formed is precipitated while the alkaline sulphate remains in solution.

These are the earths at present known, and of these are composed all rocks, stones, gems, and soils, that are found throughout, and constituting the globe. Some of these minerals contain but one earth; but minerals are found in which the earths are combined in different proportions by processes which produce that apparently endless variety of objects which mineral nature presents for our contemplation.

It may now be asked if these distinct earths are all simple substances, that is, chemical elements? for if so, then the old philosophers were wrong only in their number. At the beginning of the present century, the question would have been answered in the affirmative. Prior, indeed, to the great electro-chemical career of Sir H. Davy, they were all deemed elementary matter. But science has of late years demonstrated that none of them is entitled to that character, and that they are, in fact, compounds of certain metals with oxygen—that is metallic oxides. This has been shown by the very direct method of abstracting oxygen from them, and thereby separating the metallic base. Thus, alumina is the oxide of a gray and hard metal like platinum, and which burns with great brilliancy when heated with access of air, and reproduces the earth by absorption of oxygen from the atmosphere. Silica is, in like manner, found to be the oxide of a substance which, from want of metallic lustre, has been refused a place among the metals by some chemists, while it is placed in that class of elements by others. By those who dispute its metallic nature, it is ranked along with carbon, (pure charcoal), and another analogous substance called boron. The metal of glucina is obtained in the form of a dark gray-coloured powder, which requires the burnisher to produce its metallic lustre. The metallic basis of yttria is procured in iron-gray scales; that of thorina in smaller scales of a leaden gray colour, and that of zirconia in the form of a perfectly black powder, whose metallic lustre can only be detected by means of a magnifier. These metals burn brilliantly when heated in air, and reproduce their respective earths. The metal of lime has a very decided metallic lustre, but that of magnesia has only been obtained in brown scales which require to be rubbed to bring out their lustre. The first burns with a yellowish white, and the other with a bright red light, when heated. The metals of baryta and strontia very much resemble each other, and have somewhat the appearance of cast-iron when broken into small fragments. Both burn with a deep red flame when gently heated, and reproduce their oxides.

To obtain these bases, it is only necessary to subvert the attraction subsisting between the metal and the oxygen. This is, however, not always easy of accomplishment. Several of the earths, indeed, present difficulties to their decomposition which require the exertion of no ordinary skill to surmount.

There are three other substances which, in their properties and composition, are so nearly related to the earths that they may be here enumerated. Two of these potash and soda, are well known, and are in daily use in the arts and manufactures. The third is only known to chemists, and unlike soda and potash, which are found both in the organic and inorganic kingdoms of Nature, it occurs in no organized body.

Potash, as all know, is procured by the combustion of wood and other vegetable substances; but it also occurs in some minerals of volcanic origin, as pumice-stone and leucite. The earthy residue, or *ashes*, which remain on the combustion of woody matters, being purified by washing, forms the potash of commerce; and this being freed from the carbonic acid (by boiling with lime), forms caustic potash, which, like the earths already described, is the simple oxide of a beautiful bright metal resembling silver. The metal is, however, very soft, and lighter than water, upon which, if it be thrown, it burns with a brilliant reddish white light till it disappears, leaving the water a solution of potash. Potash, combined with fats, forms soft soap, and with aqua fortis, (nitric acid) it forms nitre, the basis of gunpowder.

Soda may in like manner be obtained by the combustion of seaweeds. Like potash, it is an oxide of a very beautiful white and bright metal, which takes fire when thrown upon water (heated to about 100° F.) and burns with a brilliant yellow flame. Strange as it may seem, common culinary salt is a simple combination of this metal with the pungent gas called chlorine, so extensively used in bleaching. Glauber's salt, again, is a compound of the oxide of the metal (soda) and vitriol (sulphuric acid). Hard soap differs from this in having tallow instead of vitriol, as the combining ingredient.

It is very singular that soda, as distinguished from potash, has been known with us only of late years, whereas it was familiar to the Greeks and Hebrews. It was also known in Egypt, where it is found native, and is known by the name *natron*—which occurs in the Bible. Thus Jeremiah speaks of washing in natron (chap. ii. 22.)

Lithia was discovered as late as 1818, in minerals called petalite and triphane. It takes its name from its lapideous origin (*lithos*, stone), in which it differs from soda and potash. It however resembles these substances in its leading properties, and is like them the oxide of a white metal.

These three substances are remarkable for their caustic acrid taste, possess the power of forming definite compounds with acids, of reddening several vegetable yellows, and of changing some blues to green, and are readily soluble in water: in consequence of these properties they are called *alkalis*—of which potash is the original type.* Some of the earths manifest the same alkaline properties, though less perfectly, and are therefore called alkaline earths. Lime, baryta, strontia and magnesia are thus denominated.

There are several elements of a non-metallic nature found in the inorganic kingdom, and which will be enumerated in a future paper; but from the preceding summary, we may reckon ourselves justified in concluding that the solid strata of our globe—that is, the superficial shell with which we are acquainted—if not the vast mass of the globe itself—are

* The term *kali* is the Arabic name of the plant from which potash was originally procured, and to this the particle *al* was prefixed. The term alkali then passed into Europe, as a general name for the ashes of all plants, and has been adopted by chemists as the generic name for those substances above-named, and a number of others, found in the organic kingdom, which possess similar properties.

nothing more than masses of metals of different kinds disguised by oxygen; that they are in fact oxides, and bear evidence, in many cases, of being the products of combustion.

## ANATOMY AND PHYSIOLOGY.

### CHAPTER XIII.

#### THE CIRCULATION.

In all living bodies, not too minute for us to dissect, we find that there is a vital and highly nourishing fluid distributed all over the body, and penetrating into the intimate structure of every part, on the presence of which life in a great measure depends. This fluid is the blood.

The blood in man is of a beautiful rich crimson colour: it is not so, however, in all living creatures, for in many at the lower end of the scale it is white or colourless. In the *mammalia*, birds, reptiles, and fishes, it is red; and in the other classes of animals, with a few exceptions, it is colourless. Hence arose the mistake, which was so long committed, of supposing the lower classes to be altogether destitute of a circulation. Its eolour varies also in different parts of the body. In the minute vessels, which are like hairs, and hence called capillaries, it is colourless, because into these the red globules are too large to penetrate; in the arteries, it is vermilion; in the veins, of a strong crimson purple; and at the right side of the heart, it is almost black. It feels thick and unctuous between the fingers, and has a slightly saline taste. In regard to its heat, it varies; in some creatures being warm, and in others cold; in man, its heat near the heart is 98° by Fahrenheit's thermometer.

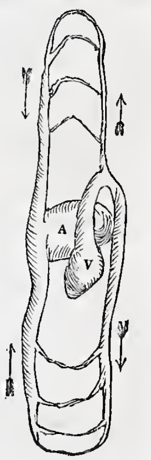
When examined by the microscope, blood is seen to be composed of an infinity of red globules, of extremely minute size, floating in a thin transparent yellowish fluid; and when drawn into a cup, these parts spontaneously separate; the red globules coagulating into a firm elastic clot, while the *serum* (so called from resembling whey) becomes clear and of a yellow colour. The clot is principally composed of an animal matter called fibrin, which, it has been already stated, is the principal constituent of the muscles. The red colour is not a necessary quality of this substance, for it can be washed out, leaving the fibrin almost white: it depends, according to some chemists, on a small quantity of iron which exists in the blood, and, according to others, on a peculiar colouring principle, different from anything existing elsewhere. The *serum* consists of water, holding in solution many salts, of which the two most plentiful are common salt and the phosphate of lime, which has been already spoken of as forming more than half the weight of the bones. The description of the blood globules has occupied a number of clever and patient investigators, but the results they have arrived at are by no means satisfactory. The latest authority gives their diameter as $\frac{1}{325}$ of a line, a line being the 12th part of an English inch.*

The proportion of the fluid to the solid part of the blood is nearly that of four to one, as minutely stated in the accompanying table, yet, from this small quantity of solid matter, the wants of all the various parts of the body are supplied. It is generally believed now, that the component parts of all the different solids and fluids of the body exist already formed in the blood, and that, in the course of its distribution, these are merely separated from it, and arranged in new combinations. This subject will be more fully examined under the head of secretion.

For the purpose of sending the blood all over the body, there are a set of tubes everywhere distributed, which are called the Arteries; and to drive the blood through them, there is an organ similar in its action to a syringe, which is called the Heart. The heart with its system of arteries is exceedingly like the system of pipes through which the water is distributed over a city: an immense mainpipe runs along the principal street, from which less ones run up the smaller streets, and these smaller ones again give off the smallest pipes which supply individual houses. The water is driven through them by an immense forcing-pump, wrought by a powerful steam-engine. In the human body, the heart represents the pump; the *aorta*, or great artery, represents the mainpipe, which gives off a number of primary branches; these again give off a certain number of secondary ones; and these divide into an infinity of minute ones, millions of which are invisible to the naked eye. And as each house in the city receives a pipe to bring water for its use, so in the body, each part receives its branch, each minute granule its twig, so that all may participate in the enjoyment of the life-giving fluid.

There is, however, a set of tubes in the circulation, which we do not see in the water-system of a city. There, if the water be used, it is allowed afterwards to run to waste. But in the body, after having vivified the parts by its presence, and deposited what was necessary for their growth and repair, the remaining quantity, not greatly diminished, is brought back again to the heart by the veins. Having been sent over from the heart through the arteries, and returned again through the veins, the blood is said to have "run through the circulation."

In this figure, we have a plan of the simplest idea of the circulation, as performed by a single heart.




V, represents the *ventricle* or strong muscular bag of the heart, which, when filled with blood, eontracts upon it, just as any other muscle does, and so forces out the contents through the pipe which arises from it, called the aorta, just as you squeeze the contents of an India-rubber bag out through a pipe fixed into its neck. The only difference is, that whereas an external force squeezes the bag, the heart, being muscular, has a power of contraction of its own; if the expression be allowable, it squeezes itself. And then, just as the India-rubber bag regains its shape when you take off the pressure, so the heart, when it has squeezed out all the blood, dilates itself again, and is ready to contract anew. It is this alternate contraetion and dilatation which constitutes the beating of the heart.

The blood having been poured into the great artery, goes through branches up to the head, and down to the lower part of the body, where its minute or capillary terminations are seen to end in veins. Those from the lower part of the body form an inferior great vein; those from the upper a superior; and the two veins terminate separately in a bag A, called the *auricle*. The *auricle* is not nearly so strong as the ventricle, because it has nothing to do with forcing the blood over the body; it is intended merely as a receptacle for the venous blood, till the ventricle be ready to receive it. Its name is derived from a Latin word signifying the hanging part of the ear, because a portion of the edge of it is exceedingly like a dog's ear. The auricle is constantly full of blood, which flows to it through the veins in an equable stream; so that whenever the emptied ventricle dilates, the blood from the auricle rushes in, and distends it for a renewed contraction.

But the arteries are not a set of rigid tubes; they are dilatable, and highly elastic. Hence at the moment when the ventricle contracts, the blood which is forced into them

* Lecanu's analysis of the blood is as follows:—

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|---|---|---|---|
| Water, | 786·500 | Chlorides of soda and potass, alkaline, phosphates, sulphates, and subcarbonates, | 7·304 |
| Albumen, | 69·415 | Subcarbonate of lime and magnesia, phosphates of lime, magnesia, and iron, peroxide of iron, | 1·414 |
| Fibrin, | 3·565 | Loss, | 2·586 |
| Colouring matter, | 118·626 | | 1000· |
| Crystallizable fatty matter, | 4·300 | | |
| Oily matter, | 2·270 | | |
| Extractive matter soluble in alcohol and water, | 1·920 | | |
| Albumen combined with soda, | 2·100 | | |

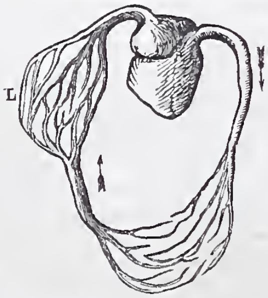
distends them, increasing their diameter, and producing the feeling communicated to the fingers placed over them, which is called *the pulse.* The number of the pulse is therefore the number of contractions which the heart is making in a minute. And at the moment when the ventricle dilates, the artery, having the distending force taken off, contracts on its contents. It would now drive part of the blood back again into the ventricle, were it not for a valve placed in the artery at its origin, which shuts down the moment the pressure comes on it backward, so that the force of the elasticity of the artery is expended in propelling the blood forward, not in an equable stream, but in successive waves. Hence when an artery is cut, the blood does not flow from it evenly, as is seen when a vein at the bend of the arm is opened, but in jets. Again, when the ventricle contracts to throw its blood into the aorta, it would throw back an equal portion into the auricle, were not a valve placed there also, which shuts the moment the ventricle contracts. The valves are named from their situation, the first being the *aortic*, and the second, the *auriculo-ventricular*.

If the blood could be constantly circulated in the same state, this simple apparatus would suffice. But in passing through the circulation, it acquires certain impurities, derived from the wearing out of the parts through which it passes, and it is requisite that these should be got rid of, before it is permitted to make another circuit. For this purpose it is brought into contact with the air in the lungs, so as to be purified, and be changed from the dark purple colour which it acquires in its passage over the body, and be brought back again to its original scarlet. This is done in several different ways; in some creatures by a modification of the heart, in others by a change in the arrangement of the arteries and veins.

In fishes, the heart is single, just as has been described. The aorta, before giving off any branches to the body, divides into two branches, one to each side, and each of these subdivides into four, one for each plate of the gills. Two of these on each side are cut off in the figure, lest it should appear confused. In the gills, the blood is exposed to the chemical action of the air, which is constantly mingled with the water. Afterwards, these branches reunite into a trunk, which then subdivides to supply the different parts of the body. It is plain that a fish's heart is constantly circulating venous or impure blood.

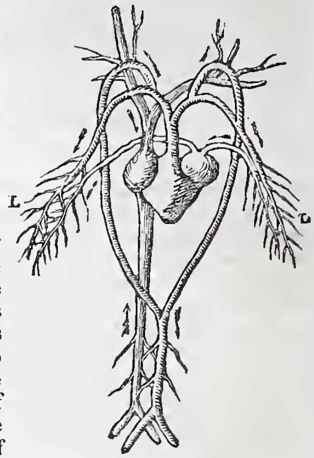
Plan of the Circulation in a Fish.

In the crab and lobster, the heart is single too, but it circulates pure or arterial blood. The blood passes from the heart to the body, then is collected, in an impure state, into a vein, which again subdivides and allows it to reach the lungs, whence it returns in a pure arterial state to the auricle, and is ready to be sent out by the verticle afresh.



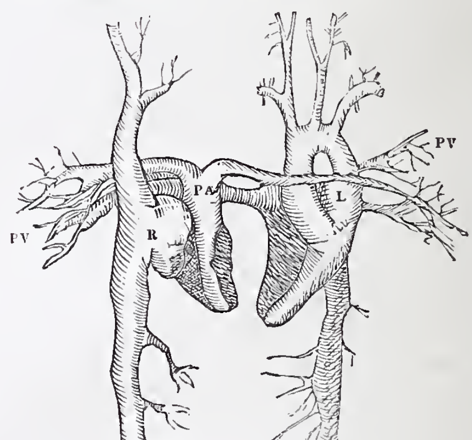
Plan of the Circulation in a Crab.

In amphibious animals, such as the frog, the circulation may be said to be less perfect, inasmuch as the whole blood is not purified between the times of its being sent over the body; and yet the heart is more complicated, being provided with an additional chamber. The great artery is seen to divide into a right and left branch, each of which again divides, giving a branch to the lung, and a branch to the body. The impure blood from the body returns into a right auricle by two great veins, and the pure blood from the lungs comes into a left auricle by a vein from each lung, and then the two auricles pour their contents into one common ventricle, so that the blood sent over the body is neither so pure as what was in the left auricle, nor so impure as what was in the right. A low degree of purity would seem to be sufficient for the wants of these animals.



Plan of the Circulation in a Frog.

In man, and all warm-blooded animals, there are two distinct hearts, one for the lungs, and one for the system, a pulmonary and a systemic heart, one for the purple blood, and one for the scarlet. They are united together so as to form one organ, that they may take up little room, and act simultaneously, the one contracting and dilating at the same time exactly as the other; but still they are quite separate in their cavities, having no communication between them, except the circuitous one round through the lungs. In man, the pulmonary heart is placed to the right, and rather in front, the systemic one to the left, and rather behind.




In the accompanying figure, the double heart is represented as separated into its right and left portions.* The right heart R, is seen with its two great veins, an upper and a lower, entering the right auricle. Below the auricle is seen the ventricle, from the upper part of which the pulmonary artery, P A, arises, and divides into two branches, one for each lung. The blood having passed through the lungs, is collected by the pulmonary veins, P V, and poured into the left auricle L, from which it reaches the left ven-

* In the Dugong, an animal somewhat like the seal, the right and left portions of the heart are separated nearly as much as in this imaginary figure.

tricle, and is by it sent over the system through the aorta. The aorta A is seen to rise first, and make an arch, from which three large branches go off, supplying the two sides of the head and the two arms; and then it goes down through the belly, giving branches to its contents, and dividing into two terminal branches for the lower extremities. We have here, then, two circulations going on at once, the lesser, or pulmonary, and the greater, or systemic.

In the real body, the two hearts are joined, so as to form a single organ. The right ventricle lies more in front, and a hollow line passing obliquely from the base towards the apex, separates it from the left. The left ventricle is longer and narrower than the right, and its point forms the apex of the heart. The right auricle is seen at the base of the heart, when in its natural place, while only a small portion of the left, that part which is like a dog's ear, is visible. Rising from the centre of the base of the heart, is the aorta, or great artery of the system; on the left side of this is the pulmonary artery, or that for carrying the impure blood to the lungs, and on the right side is the great vein of the head and upper extremities. Below, the great vein of the lower part of the body is seen, passing up to enter the right auricle. The pulmonary veins are two on each side, bringing the blood from the two lungs into the left auricle.

In examining the interior of the heart, it is most convenient to follow the course of the circulation. If the right auricle be opened, it will present the two orifices of the great veins, and they will be found not to enter opposite to one another, but obliquely, in order that the two currents of blood may not strike one another directly, and so impede one another from entering. On the partition between it and the left auricle is a hollow, marking the place where before birth there was a direct communication between the two sides of the heart. Each of the great veins is large enough to admit a man's thumb, and the auriculo-ventricular orifice, or hole leading from the auricle into the ventricle, will easily admit three fingers. The right ventricle is thin in its walls, because it has to force the blood only through the lungs; in general it is about a quarter of an inch in thickness. There are three valves in the auricular opening, whose edges are fixed to a number of tendinous threads, preventing them from being pushed back into the auricle by the pressure of the blood upon them at the time of the ventricle's contraction. No drawing can give any idea of these valves, so a figure of them has not been inserted. The orifice of the pulmonary artery is guarded by three valves also, to prevent regurgitation into it while it is dilating, and being filled from the auricle.

The left auricle has four openings leading into it, of the four pulmonary veins, two from each lung. The auriculo-ventricular orifice is smaller than that on the right side, admitting only two fingers. The left ventricle is three times thicker and stronger than the right, because it has the much harder duty of propelling the blood all over the body. The valve between it and the auricle has only two flaps, similar to those on the right side; and the orifice of the aorta has three, similar to those in the pulmonary artery, but stronger, on account of the greater force which they have to resist.

The outside of the heart is covered with a smooth shining membrane, which enables it to glide in a bag in which it is placed, called the *Pericardium.* This bag is lined with the same membrane which covers the surface of the heart, so that both surfaces being moistened constantly by a watery exhalation, the friction may be lessened almost to nothing. Occasionally the water becomes collected in considerable quantity, causing dropsy of the pericardium, and sometimes the inside of the bag becomes inflamed, and the two surfaces grow together,—an unnatural state, which, if it do not produce death at the time, generally brings on disease of the heart at an after period, by reason of the impediment which it gives to its motions. The outside of the bag is placed upon the upper surface of the diaphragm, or floor between the chest and belly—its back part is in contact with the spine—its front is touching the breast-bone and ribs, and its top is nearly at the root of the neck. The heart extends from the third to the seventh rib on the left side, and its point is felt beating at two inches below the left nipple, and an inch nearer the breast-bone. It is of importance to have these limits accurately marked out, because they enable us readily to detect any changes produced by disease.

If the ear be applied to the chest over the heart, either immediately, or with the intervention of the wooden instrument called a *stethoscope,* certain sounds are heard, produced by the heart in its action. The French denote them by the word *tic-tac,* which represents them pretty accurately. The first sound is heard at the time when the ventricles contract and strike the ribs; the second, of a sharper and more abrupt character, is heard when they dilate. The medical man requires to be well acquainted with the natural sounds of the heart, that he may be able to detect any changes produced by disease. When the valves become ossified, and the openings contracted, various curious sounds are heard, resembling the blowing of a pair of bellows, the rasping of a file, the purring of a cat, the cooing of a dove, each of which is now ascertained to indicate a particular form of disease.

Besides the disease of the valves of the heart, there may be alterations taking place in the muscular substance. Sometimes the cavities of the heart become dilated, or much larger than they should be, and consequently weaker; and sometimes the walls become much thicker and stronger, so that the blood is circulated with unusual force. These conditions generally bring on dropsy, and the last often produces apoplexy; and they are usually accompanied by palpitations, which are just irregular beatings of the heart. Palpitation does not, however, always indicate disease affecting the structure of the heart, but is frequently nervous, depending on weakness from loss of blood, or other causes, or on disorder of the stomach, or even on mental emotion. We often hear a broken heart spoken of; yet, though common enough in a figurative sense, it is in reality a very rare occurrence. The author has, however, in his museum, the heart of an elderly man, which affords a real specimen of this accident. The heart was much dilated, and one night the patient died suddenly. On examination, the left ventricle of the heart was found burst; the hole admitted a large quill, and the pericardium was found completely filled with the blood which had escaped. The heart is generally about the size of the fist of the owner; at least that is an approximation which enables us to judge of it, on opening a body, whether it be natural, enlarged, or the reverse.

## GEOLOGY.

### CHAPTER XI.

#### SILURIAN SYSTEM.

Geology had made considerable progress, and names had been assigned to the various systems of stratification, before the Silurian rocks* were brought into that notice which their great importance demands. The primary schists were followed in the geological nomenclature by the transition or the greywacke rocks—strata in which organic forms were considered as developing their earliest existence. We owe it, however, to the united labours of Professor Sedgwick and Mr Murchison to have rescued these rocks from comparative oblivion, and to have placed them in that prominent position which the phenomena they present entitle them to hold.

In our last article, we described the nature of the Cambrian or slate rocks, and noticed what may be termed the first introduction of animal existence into our planet. The want of organic remains in the Scottish schists and greywackes was alluded to,

* It may be observed, that the most eminent of our systematic geologists have lately proposed to subdivide the English sedimentary strata below the old red sandstone, into two leading groups, the lower of which is the Cambrian, already described, and the upper or newer group, to which Mr. Murchison has applied the name of Silurian, because these rocks are most fully developed in that part of England and Wales which was included in the ancient kingdom of the Silures.

and their extraordinary mineral development. In Scotland, the truncated edges of the schists are almost everywhere overlaid by old red sandstone, and we have no really authenticated representations of the Silurian rocks of Shropshire and the adjacent counties of Montgomery, Denbigh, Carmarthen, and Pembroke, though such occur in Ireland, and on various parts of the continent of Europe, and in the United States of America.

Regarded as an aggregate, the rocks of the Silurian system are less slaty than those of the older schist, and consist of freestone, flagstone of various colours, calcareous sandstone, argillaceous limestone and shale, and average from 7000 to 8000 feet in thickness.

These rocks have been divided into four groups, named according to the places where the prevailing characters of each formation is most perfectly exhibited—namely, the Ludlow, Wenlock, Caradoc, and Llandeilo rocks. These form what are termed the upper and lower Silurian rocks, and their characters and order of succession are explained in the following table:—

UPPER SILURIAN ROCKS.

| Formations. | Members. | Prevailing Lithological Characters. | Thickness. | Organic Remains. |
|---|---|---|---|---|
| Ludlow. | Upper Ludlow. | Micaceous grey sandstone. | feet. 2000 | Marine molluscs, of almost every order, the Brachiopodous most abundant. Serpula, Corals, Sauroid fish, Fuci, (sea-weeds.) |
| | Aymestry limestone. | Argillaceous limestone. | | |
| | Lower Ludlow. | Shale, with concretions of limestone. | | |
| Wenlock. | Wenlock limestone. | Concretionary limestone. | 1800 | Marine molluscs of various orders as before. Crustaceans of the Trilobite family. No vertebrated animals or plants |
| | Wenlock shale. | Argillaceous shale. | | |

LOWER SILURIAN ROCKS.

| Formations. | Members. | Prevailing Lithological Characters. | Thickness. | Organic Remains. |
|---|---|---|---|---|
| Caradoc. | Caradoc sandstones. | Flags of shelly limestone and sandstone, thick bedded white freestone. | 2500 | Crinoideans, Corals, Molluscs, chiefly Brachiopodous, and Trilobites. |
| Llandeilo. | Llandeilo flags. | Dark coloured calcareous flags. | 1200 | Molluscs and Trilobites. |

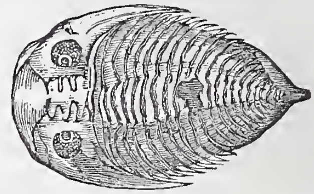
In describing these, we shall, according to our usual method, proceed from the lower to the higher strata, that we may the more effectually convey to the reader that clear and distinct view of the operations of Nature, whilst introducing organic existence into our planet, which is one of the great objects of these papers.

In the Cambrian or slate rocks only a very few fossils have been discovered, perhaps not more than thirty species. "It may surprise," says Professor Philips, "the speculators in cosmogony to hear, that these, the most ancient forms of life known to us, should not be plants, but animals; not merely zoophytes, but conchifers; not the lowest grades of their respective classes, but perfectly developed lamelliferous zoophytes and brachiopodous molluscs. Whether at the time of the formation of these ancient rocks in the sea, plants were growing on the land; whether indeed there were any land, we must not even conjecture; that plants might be growing in the sea which nourished the shells and zoophytes of Snowdon, is a probable but not a certain inference, since seaweeds do not alone constitute the food of conchifers and zoophytes." We shall now notice the different members of the system in their order.

1. The lowest member of the Silurian system, the Llandeilo flags, consist of hard, dark, gray-coloured flags, often calcareous in their composition, together with sandstone and arenaceous or clay schists, with veins of calcareous spar. It is in this portion of the Silurian rocks, where the trilobites make their first appearance, a family of extinct crustaceans, the history of which tends to throw considerable light on the ancient condition of our earth. Of these singular creatures, the Llandeilo flags present us with five genera comprehending 11 species.

2. The Caradoc sandstone appears in large mountain masses in the counties of Montgomery and Denbigh. In Carmarthenshire there is a singular tract which exhibits some very extraordinary contortions of the strata of this portion of the system, which is readily determined by the great abundance of pentameri and other characteristic fossils; "while the proofs of plutonic action appear in the existence of planes of cleavage, distinct from, yet nearly resembling those of, stratification, and in some cases, even cutting through the organic remains. These cleavage planes are always parallel, while the surfaces of the beds are often curved. There is no spot indeed, Mr Murchison remarks, in which the distinctions between cleavage and joints are better defined than in this rugged tract." "It is facts like this," continues a writer in the *Edinburgh Review*, "which lead us to doubt whether some of the slaty masses now called Cambrian, may not have been originally Silurian rocks, in which the characters have been either wholly or in part defaced by plutonic action." The organic remains of the Caradoc sandstone are much of the same character as those of the Llandeilo flagstones.

3. *Wenlock Shale.*—This formation consists of clay-shale of a dull gray, or olive colour, containing concretions of earthy limestone. The only crustaceans in this formation are the Asaphus caudatus, and Longi caudatus, two new species: the first is figured on the margin.



A. Caudatus.

4. The Wenlock limestone ranges in Shropshire for about twenty miles from south-west to north-east, with the escarpment of the Aymestry limestone running nearly parallel to it at the distance of about a mile. Both limestones are prominent while the intervening shales have been denuded owing to their greater softness. This limestone and that of Dudley are equivalent. It consists generally of large concretionary masses of pure limestone, frequently crystallized into calcareous spar, denominated "ball-stones," which are separated by intervening layers of coarser dullish-gray calcareous matter, called "measures." The spar is commonly white, but sometimes of a beautiful pink colour. The "ball-stones" are sometimes thirty feet in diameter, and are used as a flux at the adjoining iron-works. The Wenlock and Dudley limestones are remarkable for the number of coralline remains which they contain. Of these 35 genera, comprising 70 species, have been described. The multitude of these remains—which are also common to the contemporaneous limestone of Eifel—together with their mode of aggregation, have, indeed, suggested the notion of these rocks being in fact ancient coral reefs. Perhaps the most abundant and characteristic of the organic forms exhibited is the chain-coral, called systematically *Catenipora escharoides*.

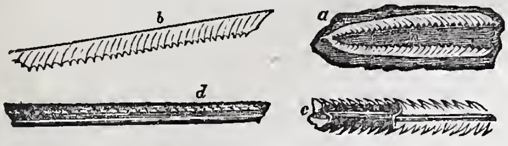
Catenipora Escharoides.

5. *The lower Ludlow Rocks.*—These form the basis of the upper Silurians, and consist of sandy shale and flags of a dark-gray, or liver colour, with concretions of earthy limestone. It is in these beds where the remains of fishes are first found. Trilobites also occur in this and in the two superior members—namely, the Aymestry limestone, and upper Ludlow rock.

6. *Aymestry Limestone.*—The limestone measures generally about 50 feet in thickness, and is of an argillaceous subcrystalline character, and of a blue or deep gray colour. It forms an excellent cement under water.

7. *Upper Ludlow Rock.*—This member consists of thin beds of soft subcalcareous sandstone; gray and greenish, sometimes passing into limestone, but near the top scarcely distinguishable from the lower beds of the old red sandstone, except by its fossils. These beds are seen emerging from beneath the old red sandstone strata along a zone or band, extending from the hills near Ludlow, on the north coast, to the sea cliffs at the south-west extremity of Pembrokeshire, a distance of about 150 miles. The *Lingula cornea* is common to the upper part of this groupe, and to the lowest or tilestone beds of the old red sandstone, and a short distance below the junction is a stratum of great interest from its abounding in the confused remains of fishes, which Dr Lloyd of Ludlow was the first to discover and bring into notice. The remains in the central portion of the upper Ludlow are unusually perfect. In the fine argillaceous shales, known provincially as "mudstones," from their tendency to dissolve into mud

on exposure to the weather, many zoophytes are found enveloped in an erect posture, having evidently become fossil on the spots where they grew at the bottom of the sea. Among others, the sea-pens (*graptolites*) are very abundant.



*a, b,* Graptolites from Christiana, Norway.
*c, d,* Graptolites from the south of Sweden.

The whole combined character of this member is indeed that of tranquil deposition; the sandstones are ripple marked, and the facility with which the shales are melted down by the weather, proves that notwithstanding their antiquity, they are simply the mud and slime slowly accumulated at the bottom of the ancient sea, hardened by compression.

This is a brief outline of the Silurian system. Its organic remains admirably illustrate the gradual manner in which it has pleased the Deity to introduce animal forms into our world. From a few obscure species found in the Cambrian or Slate Rocks, we gradually ascend in the scale of creation through the long period of sedimentary deposition, indicated by nearly 8000 feet of rocks, evincing little disturbance or violence in the agencies of deposit. We observe in each new period the introduction of new genera and species, confined, indeed, to the lower classes of animated existence—such as corals, and the inhabitants of shells and crustaceans; yet some of these organizations assume a very complicated structure, and evince an exercise of power and mechanical contrivance utterly at variance with the atheistical notions of all being the result of fortuitous causes, and merely the operations of the inherent capabilities of matter. To one acquainted with the anatomy of the Nautilus, a genus found in the Silurian rocks, and still extant in the Mediterranean and other seas, this will appear sufficiently obvious; and the conviction of the application of contrivance by the Architect of nature in the very earliest stages of the exercise of his creative power in this our planet, will be rendered still more obvious if we contemplate the structure of the extinct Trilobites, a family confined almost exclusively to the Silurian period, the rocks of which present us with 10 genera, comprising 38 species, or according to Dr Buckland, 52 species.

"In the comparison made," says Dr Buckland, "between the four different families of Crustaceans, for the purpose of illustrating the history of the long extinct Trilobites, by the analogies we find in the Serolis, Limulus, and Branchipus, we have a beautiful example taken from the extreme points of time of which geology takes cognizance, of that systematic and uniform arrangement of the animal kingdom, under which every family is nearly connected with adjacent and cognate families. Three of the families under consideration are among the present inhabitants of the waters, while the fourth occur only in a fossil state. When we see the most ancient Trilobites thus placed in immediate contact with our living Crustaceans, we cannot but recognise them as forming part and parcel of one great system of creation, connected through its whole extent by perfect unity of design, and sustained in its minutest parts by uninterrupted harmonies of organization.

"We have in the Trilobites an example of that peculiar, and, as it is sometimes called, rudimental development of the organ of locomotion in the Crustacean class, whereby the legs are made subservient to the double functions of paddles and lungs. The advocate for the theory of the derivation of more perfect species existing by successive changes from the more simple ancient forms, might imagine that he sees in the Trilobites the extinct parent stock from which, by a series of developments, consecutive forms of more perfect Crustaceans may, during the lapse of ages, have been derived; but according to this hypothesis, we ought no longer to find the same simple condition as that of the Trilobites, still retained in the living Branchipus, nor should the form of the Limulus have possessed such an intermediate character, or have remained unadvanced in the scale of organization from its first appearance in the carboniferous series, through the mid-way periods of secondary formations unto the present hour."

The Trilobites were animals possessed of a three-lobed shield or plate, the hinder part of which was divided into segments, like that of the lobster, and like it capable of being folded up. In the fore part of the shield, as in the Limulus, were placed compound eyes, adapted to produce vision through the medium of a number of lenses placed at the extremity of an equal number of conical tubes, or microscopes. "In the Asaphus Caudatus each eye contained at least 400 such lenses, fixed in separate apartments on the surface of the cornea." The form of the general cornea is peculiarly adapted to the uses of an animal destined to live at the bottom of the water, and, accordingly, such is the construction of Crustaceans of the class we are describing. The conformation of the eyes of the Trilobite and its cognate genera, not only demonstrates the most exquisite adaptation of the parts for the peculiar habits of the animals to which they belong, but the nature of the media in which they lived. To a creature, living at the bottom of the water, it was impossible to look downward, and therefore the eye of the Trilobite was constructed for horizontal and upward vision in every direction. "The form," says Dr Buckland, "of each eye is nearly that of the frustum of a cone, incomplete on that side only which is directly opposite to the corresponding side of the other eye, and on which if the facets were present, their chief range would be towards each other across the head, where no vision was required. The exterior of each eye, like a circular bastion, ranges nearly three-fourths of a circle, each commanding so much of the horizon, that where the distinct vision of one eye ceases, that of the other eye begins, so that in the horizontal direction the combined range of both eyes was panoramic." Eyes so distinctly constructed as those of the Trilobite, and so fitted for distant vision, instruct us as to the nature of the water in which they existed, and the conditions of light at the very earliest epoch of animal existence, conditions which must have been similar to those that now exist. In contemplating the list of Silurian fossils, furnished us by Murchison aud Sedgwick, we are naturally struck with the entire absence of vertebrated animals in all the rocks older than the lower Ludlow, in which only one species, and that a fish, makes its appearance. The construction of the eyes of the Trilobite, and the identity of many of the Silurian genera, of both corals and shell-fish, with those now living, show that though the species differ, no great, if any, difference existed in the waters of that period from those of the present day. To suppose, therefore, that any power existed in that fluid beyond what it now possesses to produce the original types of organic forms, either by transmutation of species, or by some occult natural agency, resident in mere matter, is contrary to common sense, and seems averse to all the conclusions we can draw from the laws which regulate matter. Although organic nature is linked together by insensible gradations, yet such is the permanency of genera, if not of species, that no greater absurdity presents itself to the student of Nature than the idea of a Crustacean begetting a vertebrated fish, or an oyster merging into a lobster; and yet to greater absurdities than this does materialism lead. It is true, we can form no idea of the mode by which creation was performed—of the *modus operandi* of the Almighty Architect, in framing even the meanest of his productions; but it is our high privilege to investigate the structure, to admire the workmanship, and its adaptation for the purposes for which it exists. This is enough, and we must rest satisfied, that beyond this high commission we cannot proceed.

## DOMESTIC MEDICINE.

### CHAPTER IV.

ON THE PHYSICAL CAUSES OF DISEASE—(CONTINUED.)

FOR the continuance of health, it is absolutely necessary, as we can now understand, that every organ of the body execute the office assigned to it with regularity and perfection. The human clockwork is so accurately balanced, and so intimately connected, that no part of the mechanism can be materially deranged without deranging the whole,—the main difference, indeed, between a strong constitution and a weak, consisting in the different degrees, which all the organs pos-

sess, of the power of resistance to the ordinary causes of derangements to which they are liable. The blood, as we have already seen, must be equally distributed over the whole system. If an organ be supplied in too great quantity, its healthy action will be immediately interfered with; and, by a continuance of this extra supply, disease will be produced. An overflow of blood, if directed upon the brain, will excite inflammation, apoplexy, or palsy; if upon the organs of respiration in the chest, it will excite catarrh, influenza, bronchitis, pneumonia, or pleurisy; if upon the stomach, liver, or other organs of digestion, the consequence will be inflammation of some of these organs, or diarrhœa, dysentery, or cholera; if upon the joints, it will excite rheumatism, &c. But how can we know when these irregularities in the circulation, and dangerous determinations of blood, are about to occur, so as to be able to provide against their injurious effects? Our remarks in last chapter show that one of the principal causes of irregular distributions of blood, and of consequent disease, is *exposure to cold*, and to *sudden vicissitudes of temperature*. "With the exception," says Dr. Bateman, "of a small number of diseases occasioned by unwholesome occupations, and by the contagions, the great mass of human malady in this metropolis is referable to the climate or state of the seasons, and to *intemperance;* but of these two causes, the *vicissitudes of the weather*, especially its *cold*, are by far the most prolific sources of mischief."* By a wise and beneficent provision of Providence, our bodies are so constituted as to serve us for natural *thermometers*, or measurers of the degrees of heat and cold, conveying to our minds, by our sensations, accurate information as to when we ought to take alarm, and secure ourselves against impending danger. If we were sufficiently careful to avail ourselves of these natural warnings—to look upon an abiding sensation of chilliness with the same dread as we look upon the contagion of fever—these irregular distributions of blood, and the diseases they produce, would be of much more rare occurrence.

The great counteracting influence possessed by the animal body against the pernicious effects of cold, is its inherent power of evolving animal heat; and according to the different degrees in which this power is possessed and preserved, will it be more or less able to resist the influence of sudden vicissitudes of temperature. But it is well known that the power of evolving animal heat depends on the strength and vigour of the circulation; and whatever tends, therefore, either temporarily or permanently, to increase the vigour of the circulation, such as exercise, good food, warm clothing, stimulants, &c., increases, either temporarily or permanently, the power of evolving animal heat; whatever, on the contrary, diminishes the strength of the circulation, such as want of exercise, long fasting, fatigue, debauchery, night-watching, disease, &c., diminishes the power of evolving animal heat, and greatly augments the liability of the body to be affected by those diseases which arise from exposure to cold. The truth of these remarks is frequently exemplified by the narrations of navigators in the polar seas. It is related in the "Narrative" of Sir John Franklin—to whose name such a painful interest has been attached for several years, and whose present situation and condition is involved in such impenetrable mystery—talking of one of his journeys in the polar regions, that, "During our march we experienced that no quantity of clothing could keep us warm while we fasted; but on those occasions on which we were obliged to go to bed with full stomachs, we passed the night in a warm and comfortable manner. Our good cheer (towards the close of their toils, when they had got a proper supply of food) gave such power of resisting the cold, that we could scarcely believe otherwise than that the season had become milder."

As long, therefore, as the vigour of the circulation is kept up by any means, a person is exposed to little risk from the pernicious effects of cold in whatever circumstances he may be placed. Is he a sportsman—habituated to the refinements of a city life and the delicacies of the drawing-room—drenched with rain on a Highland moor, or saturated with wet on the river's side? As long as he continues his exercise, with his mind excited and eager after his sport, the strength of the circulation is kept up. Whenever his amusement for the day is over, he *walks* quickly home, changes his dress, takes a little of some stimulant, enjoys a good dinner, and no bad effects ensue; but were he to sit down wet, heated, and fatigued, on the hill-side, take a draught of cold water, and above all, were he to go to sleep for a little, inflammation of some bodily organ would be certain, and even death itself might be the result. Is he a pedestrian, bathed in perspiration, or, which is the same thing, overtaken by a heavy rain and thoroughly wet; and is he obliged to halt for a little, with no opportunity of shifting his clothes? Then he must have recourse to artificial means to keep up the vigour of his circulation, and to obviate the evil consequences which might ensue;—the best means for this purpose being a wine-glassful of brandy or whisky, or a bottle of warm ale or porter, followed as soon as possible by a hot meal. Is he a labourer, perspiring profusely by the severe exercise to which he is subjected on the harvest field, or at any other active employment? He must occasionally relax the constant tension of his muscular system by intervals of rest; but, ignorant of all the physical causes of disease, he sits down, half naked, on the damp ground, or perhaps on a cold stone, opens up his reeking chest to the cool breeze, and takes large draughts of cold water or beer; and thus are laid the foundation of the greater number of diseases with which a rural population are affected. During their intervals of rest, these labourers ought to take every means, particularly if there is a cool breeze blowing at the time, to prevent the body from cooling quickly, and the perspiration from being suddenly dried up. For this purpose they ought to put on their clothes, take whatever shelter they can get, and avoid cold drinks till a little *after* they have again commenced their labours. Habitual exposure to the open air certainly exerts a protecting influence in such cases: the system is strengthened, the circulation acquires a permanent force and vigour, the body becomes inured to the influence of cold, and less susceptible of sudden changes of temperature; and far fewer of those who pursue out-door occupations fall victims to the pernicious effects of cold, than of those whose employments or *inclinations* confine them to warm rooms, and prevent them from taking sufficient exercise in the open air.

The reason that wet or moisture, either from water or perspiration, has such a powerful effect in producing cold, is from the constant tendency which all fluids have to pass off into the atmosphere in the form of vapour; for, to enable them to pass into vapour, they require, as was already mentioned, a great amount of heat; consequently, they are continually robbing the surrounding air and all adjacent bodies of a portion of their heat. The evaporation of fluids is also much quicker accomplished, the stronger the current of dry or heated air which passes over them. On a dry and windy day, the evaporation from the wet ground goes on quickly; by this means the earth and atmosphere are cooled down, and the temperature reduced; whereas, if it be calm, the evaporation will go on slowly, and it will feel close and warm. On the same principle, the bad effects of cold are often produced by washing the floors, and drying wet clothes in rooms inhabited by delicate people and children, from the evaporation reducing the temperature. Dr. Alison, of Edinburgh, says he has frequently observed that, in the low parts of the town, children were seized with croup on *Saturday night*, this being the night on which the poorer classes wash their floors, and often dry their clothes in the rooms in which they live and sleep. On the same principle, also, does wet and moisture applied to the surface of the body, either from water or perspiration, operate in reducing the temperature by evaporation, and the sooner will the temperature be brought below the healthy standard and disease produced, the weaker the circulation, or, in other words, the less the power of evolving heat. As long as the circulation is vigorous—as long as a superabundance of animal heat is evolved, the perspiration has the salutary effect of keeping down the temperature of the body. A person may expose himself to the most sudden

* Observations on the Diseases of London.

alternations of temperature with impunity; he may plunge into the sea while bathed in perspiration; he may leave a vapour bath, and roll himself in snow; or he may go from a ship's cabin, where the temperature is at 50°, into an atmosphere 70° below the freezing point, without the slightest danger to his health; but the moment the strength of his circulation begins to flag—the moment a sufficiency of heat ceases to be evolved—the moment an *abiding sensation of chilliness* is produced, then is there real cause for alarm; and if the salutary warning which is given by the feelings be neglected, disease more or less severe will be sure to follow. The demand for a proper quantity of animal heat to counteract the influence of cold continues as great as ever, but the supply of fuel is stopped, the fire of the circulation is languishing, the evolution of heat is arrested, and unless exercise, cordials, additional clothing, or a warmer atmosphere be had recourse to, the occurrence of disease will be next to certain.

What we have to bear in mind, then, is, that whatever quickens the circulation, such as exercise, a heated atmosphere, &c., causes more heat to be evolved than is necessary for keeping up the temperature of the body, and this superfluous heat is got rid of by perspiration, which is poured forth in greater or less quantity, according to the increased activity of the circulation. If the external air be cold, if a strong breeze be blowing, and if the clothing be light, this perspiration is carried off, or evaporated, in an *insensible* form as soon as it breaks forth: if, on the other hand, the atmosphere be warm or calm, or if the body be covered by much clothing, the perspiration is not evaporated, but appears in a *sensible* form, and wets the under clothing. As long as the increased force of the circulation is kept up by exercise or any other means, the perspiration performs the important office of keeping down the temperature of the body to the healthy standard, enabling us to endure the most violent exercise, the burning heats of a tropical climate, or even to remain for some time in a heated oven, with the animal temperature increased but to a very slight degree. But when the cause of this increased circulation and perspiration ceases to operate, matters become totally changed: the perspiration then, instead of being beneficial, acts in exactly the same manner as wet from rain or any other cause; the superfluous heat has ceased to be evolved, still the wet or perspiration goes on evaporating and robbing the surface of the body of its heat till it be dried up; and by this means the blood is repelled upon the internal organs, and disease is produced. It is evident that the thinner the clothing, the colder the air, and the stronger the breeze, the quicker the evaporation goes on, and the sooner is the body robbed of its heat; hence the use of flannel or woollen next the skin, which absorbs the moisture and checks the rapidity of the evaporation. It is not, therefore, while the increased force of the circulation by whatever cause continues, although the surface of the body be wet or bathed in perspiration, that there is any danger; it is when the cause of the increased vigour of the circulation is suddenly stopped—when the body is cooling after being heated, that there is cause for alarm.

There are several ways by which the bad effects likely to result from such a cause can be obviated: either to prolong the exercise, gradually lessening its severity, till the wet or perspiration be dried up; to keep up the vigour of the circulation by some stimulant or cordial till the same thing occur; to diminish the cooling effect of the evaporation by removing to a warmer atmosphere, or putting on additional clothing; or to throw off the wet garments, dry the skin thoroughly, and put on warm and dry clothes. A combination of these measures is generally the most effectual: to take some cordial or stimulant, such as brandy, whisky, or porter, mixed up with hot water; to remove the wet clothing and put on dry, having first dried the skin well, and reddened it with flesh brushes or a coarse towel; the friction will not only aid in stimulating the capillaries and perspiratory pores, but the exercise necessary in this operation will increase the vigour of the circulation, and produce a healthy reaction, by impelling the blood to the extremities and surface of the body. It is very remarkable, that we see many of these measures adopted to prevent disease in horses, and quite neglected by the majority of human beings in their own persons. The skilful owner of a favourite horse, instead of sending him carelessly away to his stall after having overheated him by exercise, will order him to be walked about till he get somewhat cooled, to be then well rubbed down and covered up with a cloth, and afterwards to have a warm drink, well knowing that, if he neglected these precautions, colic, inflammation of the bowels, or some other disease, would in all probability supervene. Training-masters, also, whose object it is to develop the highest degree of muscular strength which the human body can attain, and who, in preparing their pupils for the "ring," must "sweat them down" by violent exertion, invariably make them change their dress after each exercise, cause them to wear flannel next their skin, and, even for their mid-day's repose, make them undress and go to bed. On being asked the reason of their scrupulous adherence to these rules, they say their object is "not to throw away a chance," but to avoid the smallest risk of rheumatism or cold.

From the preceding observations it may naturally be inferred, that those diseases which arise from exposure to severe cold would be more prevalent and more fatal in winter than in summer, and that the colder the winter the greater would be the mortality. Accordingly we find, from the valuable annual "Reports of the Registrar-General of Births, Deaths, and Marriages, in England and Wales," that the mortality from these diseases varies exactly with the temperature. In the third annual report it is stated, that "the causes of death which prove most fatal in the cold months belong principally to the pulmonary class, and the cerebral diseases of the aged: those which prove most fatal in summer belong to the diseases of the bowels."

From the ninth annual report we extract the following statistics regarding some of the special causes of death in London, in each of the four quarters of eight years, from 1840 to 1847 inclusive.

*Deaths from Diseases of the Lungs and other Organs of Respiration, including Pneumonia, Bronchitis, Pleurisy, &c.*

| Years. | Winter Quarter, ending 31st March. | Spring Quarter, ending 30th June. | Summer Quarter, ending 30th Sept. | Autumn Quarter, ending 31st Dec. |
|---|---|---|---|---|
| 1840 | 3,945 | 3,258 | 2,833 | 4,145 |
| 1841 | 4,604 | 3,441 | 3,001 | 3,367 |
| 1842 | 4,325 | 3,230 | 2,870 | 3,810 |
| 1843 | 4,048 | 3,442 | 2,750 | 4,440 |
| 1844 | 4,644 | 3,229 | 2,782 | 4,265 |
| 1845 | 4,923 | 3,478 | 2,669 | 3,567 |
| 1846 | 3,807 | 3,487 | 2,761 | 4,313 |
| 1847 | 5,981 | 3,726 | 2,652 | 6,101 |

*Deaths from Old Age.*

| Years. | Winter Quarter. | Spring Quarter. | Summer Quarter. | Autumn Quarter. |
|---|---|---|---|---|
| 1840 | 1,034 | 788 | 716 | 1,000 |
| 1841 | 1,274 | 708 | 667 | 798 |
| 1842 | 1,079 | 748 | 691 | 918 |
| 1843 | 1,111 | 839 | 619 | 980 |
| 1844 | 1,018 | 673 | 648 | 898 |
| 1845 | 1,127 | 744 | 569 | 519 |
| 1846 | 612 | 491 | 487 | 651 |
| 1847 | 971 | 664 | 540 | 957 |

*Deaths from Diseases of the Stomach, Liver, and other Organs of Digestion, including Diarrhœa, Dysentery, Cholera, &c.*

| Years. | Winter Quarter. | Spring Quarter. | Summer Quarter. | Autumn Quarter. |
|---|---|---|---|---|
| 1840 | 714 | 766 | 1,187 | 791 |
| 1841 | 883 | 758 | 982 | 825 |
| 1842 | 820 | 725 | 1,131 | 766 |
| 1843 | 781 | 835 | 1,146 | 1,002 |
| 1844 | 795 | 847 | 1,027 | 854 |
| 1845 | 981 | 860 | 1,099 | 875 |
| 1846 | 940 | 1,012 | 1,356 | 1,042 |
| 1847 | 1,030 | 1,067 | 1,284 | 1,235 |

*Mean Temperature for Five Years.*

| Years. | Winter Quarter. | Spring Quarter. | Summer Quarter. | Autumn Quarter. |
|---|---|---|---|---|
| 1842 | 39°.6 | 47°.6 | 62°.8 | 48°.2 |
| 1843 | 40°. | 47°.4 | 39°.8 | 50°.5 |
| 1844 | 35°.8 | 48°.7 | 59°.9 | 50°.1 |
| 1845 | 37°.6 | 43°.6 | 59°.3 | 49°.9 |
| 1846 | 40°.3 | 48°.3 | 64°.3 | 52°.2 |

Nothing can place in a clearer light the effects of *temperature*, in regulating the number of cases of diseases and deaths, from special causes, than these tables, extending over a number of years, and compiled with such scrupulous care and accuracy. In proportion as the mean temperature of the day and night *falls below* a certain point in winter, the mortality from diseases of the lungs, and from diseases incident to old age, increases. Compare the years 1845 and 1846. The mean temperature for the three winter months of 1845 was 37 degrees, the mortality during the same period, from diseases of the organs of respiration, was 4,923; from old age, 1,127; while for the winter quarter of 1846, the mean temperature was above 40 degrees, and the deaths, from diseases of the chest and from old age, were respectively 3,807 and 612. These facts are a complete refutation of the commonly received opinion, that a mild winter is less favourable to health than a severe. It is related in one of these reports, in detailing the influence of cold as a cause of death, that "the rise in the mortality is immediate; but the effects of the low temperature go on accumulating, and continue to be felt thirty or forty days after the extremities of the cold have passed away. The cold destroys a certain number of persons rapidly; and in others occasions diseases which prove fatal in a month or six weeks. The practical lessons taught by these facts is obvious. A great number of the aged, and of those afflicted with difficulty of breathing, cannot resist cold sunk so low as 32 degrees. The temperature of the atmosphere in which they sleep can never safely descend lower than 40 degrees; for if the cold, which freezes water in their chamber, do not freeze their blood, it impedes respiration, and life ceases when the blood-heat has sunk a few degrees below the standard."

Again, deaths from diseases of the bowels increase in proportion as the mean temperature of the air *rises above* a certain point. On referring again to the tables, we find that the deaths from diseases of the stomach, liver, and other organs of digestion, in 1846, greatly exceeded those of 1845; and, in exact accordance with this result, we find that the mean temperature of the spring and summer months of 1846 exceeded that of 1845 by 5 degrees. It was mentioned in last chapter, that a high temperature of the external air gave rise to diseases of the liver, to cholera and dysentery, &c., and the prevailing diseases of tropical climates were adduced in illustration of the truth of our remarks; these tables prove, in a very satisfactory manner, that the same effects follow the same cause in our own temperate climate.

2. *Impurity of the air, from the admixture of dead or living animal or vegetable effluvia*, may be given as the second of the *atmospheric* causes of disease. Impurity of the air cannot, perhaps, be said to give rise to any specific disease, such as cholera, fever, &c.; but it exerts such a debilitating influence upon the human constitution, as thus to make it an easy prey to any contagious or other exciting cause of disease, which may come into operation. It should therefore be looked upon rather as a predisposing, than a directly exciting cause of disease. We have only to compare the pale and sickly appearance, and the puny and emaciated forms of the children in the low, densely-crowded, ill-ventilated, dark, and filthy districts of large towns, with the ruddy cheeks, the sparkling eyes, and the cheerful countenances of the very poorest children in rural districts, to be thoroughly convinced of the highly noxious effects of continually breathing an atmosphere loaded with impurities. It need excite no surprise, therefore, to find that diseases are far more frequent and fatal, and that the span of human life is considerably abridged, under these unfavourable circumstances. By referring again to the valuable reports of the Registrar-General, we see that the deaths from consumption are 24 per cent., the deaths from typhus fever 55 per cent., and the deaths from childbirth 59 per cent., *greater* in cities than in rural districts; and in several other diseases the difference in the ratios of mortality in town and country is equally great. "The diseases incidental to childhood are twice as fatal in the town districts as they are in the country." How can it be otherwise among a class whose constitutions, hereditarily weak, are farther debilitated not only by breathing foul and contaminated air, but by being fed at breasts from which a sufficient supply of healthy, rich, and nutritious milk can never flow? "The mean duration of life in the two classes of districts differs nearly 17 years, being in the proportion of 55 years (in the country), to 38 years (in towns)." This high mortality in towns has been traced, among the wealthier classes, to want of sufficient exercise in the open air, overstimulating food and drink, late hours, &c.: among the poorer classes it has been traced to overcrowded and dirty dwellings, unhealthy occupations, personal uncleanliness, putrid effluvia from narrow and filthy streets, a deficiency of fresh air, water, and sewers.

In the ninth annual report of the Registrar-General, we find the mortality in the low, crowded, and filthy habitations in the town districts of Manchester, for the seven years from 1838 to 1844, compared to that of the extra-metropolitan parts of Surrey, and is as follows:—

"In Surrey, from 35 to 45 years of age, 11 deaths per 1000 males.
"In Manchester, from 35 to 45 years of age, 21 deaths per "

| | | Deaths Registered in 7 Years, 1838-1844. |
|---|---|---|
| "Population of the town sub-districts of Manchester in 1841,................ | 163,856 | 39,922 |
| "Population of the extra-metropolitan districts of Surrey in 1841,........... | 187,868 | 23,777 |
| Difference,...................... | | 16,145 |

| | No. of Children under 5 Years of Age. | Deaths in 7 Years. |
|---|---|---|
| "In Surrey,.. ............................ | 23,523 | 7,364 |
| "In Manchester, .......................... | 21,152 | 20,726 |
| Difference,...................... | | 13,362." |

"How pitiful," says the report, "is the condition of many thousands of children born in this world! Here, in the most advanced nation of Europe (?)—in one of the largest towns of England—in the midst of a population unmatched for its energy, industry, manufacturing skill—in Manchester, the centre of a victorious agitation for commercial freedom—aspiring to literary culture—where Percival wrote, and Dalton lived—13,362 children perished in seven years, over and above the mortality natural to mankind. These 'little children,' brought up in unclean dwellings and impure streets, were left alone long days, by their mothers, to breathe the subtle, sickly vapours—soothed by opium, a more 'cursed' distillation than 'hebenon'—and when assailed by mortal diseases, their stomachs torn, their bodies convulsed, their brains bewildered, left to die without medical aid—which, like hope, should 'come to all,'—the skilled medical man never being called in at all, or only summoned to witness the death and sanction the funeral!"

Were we to ask where do cholera, typhus fever, malignant scarlet fever, and other virulent epidemics first break out, and where do they make most fatal havoc? The answer, in accordance with the vast amount of statistical evidence collected on this subject, would be, "*almost always in dens of filth, and in low, damp, dark, and ill-ventilated places.*" The cholera made its first appearance in St. Petersburg, in Russia, among the boats, and in the parts of the town adjacent to the river. At Dantzic, the first cases occurred on two *mud barges*, on the harbour canal. In Berlin, it first appeared among the skippers in the boats, and in the district in the immediate neighbourhood of the river Spree. In Moscow, it committed the most fatal ravages in a low and

damp quarter of the town, included in a bend of the river Moskwa. At Breslau, it was by far the most fatal in the low, marshy part of the town, which is the constant seat of intermittent fever. At Warsaw, the condition of the houses in which it prevailed was little better than that of sewers. From the report of the Central Commission at Paris, it appears that its ravages were most fatal in the low, close, undrained, and uncleansed localities of that city. In its progress through Britain, it generally first appeared in the neighbourhood of rivers and marshes, and prevailed chiefly in low and damp localities, particularly where these were also the outlets of filth. In London, it first broke out on the river Thames, and was most prevalent and fatal in the adjacent districts of the town, and near ditches and the outlets of sewers. In other towns in England, it obeyed the same law. In Scotland, this tendency to prevail in low, damp, and filthy situations was strikingly exemplified in Easter Ross in 1832. It occurred during the fishing season, and its ravages among the low, damp, and filthy fishing villages on the shore of Tain was fearful, in some cases cutting off nearly one half of the inhabitants, while the town of Tain and the greater part of the rural districts escaped.

But there is abundant evidence to prove that Asiatic cholera obeys the same laws which regulate the propagation and mortality of ordinary epidemics: it attacks persons in the same circumstances, and breaks out in similar places; and it is attested by universal experience, that the same physical predisposing causes promote both the extension and virulence of all these disorders. These causes, as already mentioned, consists in whatever debilitates the constitution and weakens the powers of life, such as a deficiency of the means of protecting the body against cold, an insufficient supply of proper food, breathing an impure and humid atmosphere, intemperance, debauchery of all kinds, want of sleep and want of exercise, previous disease, &c. "It is now universally known," says the report of the Sanitary Commissioners, appointed by parliament to inquire into the means requisite for improving the health of London, "that in the metropolis, as in every town and city, the places in which typhus fever is to be found, from which it is rarely if ever absent, and which it occasionally decimates, are the neglected and filthy parts of it; the parts unvisited by the scavenger; the parts which are without sewers; or which, if provided with sewers, are without house-drains into them; or which, if they have both house-drains and sewers, are without a due and regulated supply of fresh water for washing away their filth, and for the purposes of surface cleansing and domestic use. The evidence that the track of typhus is everywhere marked by the extent of this domain of filth, has been so often adduced that it is needless to repeat it; but the evidence that, during the prevalence of cholera, this was also everywhere the precise track of this pestilence, is not so well known." The same remarks apply to the worst forms of scarlet fever and influenza, and the other contagious epidemics.

What a powerful appeal ought these facts to make to magistrates, commissioners of police, house-owners, and other influential inhabitants of towns, to enforce the strictest sanitary regulations wherever they have the power; and this not only from motives of benevolence and philanthropy, but from the more powerful motives of *self-protection!* Let not the more affluent inhabitants of towns and rural districts console themselves with the idea, that, in their more favourable circumstances, come what will, *they* are secure against all danger; once allow the demon of contagion to get a footing, and he will not be confined to his natural element of filth, wretchedness, and misery, but will overstep this bounds, and attack, often with equal virulence, the families of the middle and higher classes, scattering in his path the most dire destruction, desolation, and woe! Then will the bereaved and broken-hearted parent, the distressed and widowed mother, or the forlorn and fatherless child, have but too good cause to regret, and regret bitterly, that proper precautions were not had recourse to in time, against the inroads of the common enemy! "Difference of social grade," says the report of the Commissioners above quoted, "less exempts the individual from the attack of cholera than of fever; and cholera more often, and apparently more capriciously, bursts its natural boundaries, and attacks the inhabitants of comparatively healthier districts—among whom it then proves little less mortal than when it ravages its accustomed haunts."

3. In close connection with impurity of air as a cause of disease, is *a deficient supply of pure air.* Chemists inform us that atmospheric air is composed of two gases—oxygen and nitrogen: a sufficient supply of oxygen to the lungs is absolutely necessary for the support of animal life; but as it would prove too strong and irritating for these organs in a pure and undiluted state, it is rendered mild by being mixed with nitrogen in the atmosphere. By every breath, then, which we *inhale*, the lungs absorb a certain quantity of oxygen from the air for the purposes of life; and by every breath we *exhale*, they give out a certain quantity of watery vapour and carbonic acid, which, if detained in the body, would soon prove fatal to the living being. If any breathing animal were confined in a certain quantity of atmospheric air, and all additional supplies cut off, it would sooner or later consume all the oxygen contained in that air, which would then become highly impregnated with carbonic acid from the lungs of the animal, and it would therefore die from a deficiency of oxygen, and the poisonous effects of the carbonic acid.

Ignorance of this law of nature has, in innumerable instances, been productive of the most fatal consequences to human life. Almost every one has heard of the terrible fate of 146 Englishmen who were confined in the Black Hole of Calcutta, and of whom, at the end of twelve hours' confinement, only 23 survived, all the others having been suffocated from a deficiency of oxygen, and an excess of carbonic acid in the air they breathed. The fearful mortality in slave-ships from the same cause is also well known; and, indeed, it was beginning to be thought that a knowledge of this physical cause of disease was universally known and understood, till public attention was aroused, about two years ago, by the shocking intelligence that an immense number of human beings were suffocated, or, in other words, *poisoned*, in a ship off the coast of Ireland, by the captain's nailing down the hatches in a storm, and depriving the passengers of a sufficient supply of pure air. Although the effects are not so obvious, and it operates more slowly and insidiously, the same cause of disease is in constant operation in close, ill-ventilated, and overcrowded rooms; it is exactly the same thing whether the room be too small, or large and overcrowded: the supply of oxygen to each person becomes exhausted—he breathes an atmosphere poisoned by carbonic acid, exhaled from his own or his companions' lungs, and the result is more pernicious in proportion to the deficiency of oxygen, the excess of the carbonic acid, and the length of time he is exposed to the noxious influence.

The effects of a deficient supply of pure air, combined with a deficiency of drainage and pure water, in raising the ratio of mortality from cholera, typhus fever, influenza, bronchitis, and consumption, to an enormous extent, are but too visible in some of the close and overcrowded parts of London. One thousand cubic feet of air is considered necessary for the health of a single prisoner in England; 800 cubic feet for a soldier in India; while in the wretched dwellings and lodging-houses in Church Lane, and the neighbouring streets and alleys, as well as in the crowded courts of Gray's Inn Lane, the average for each human being is only 175 cubic feet—the highest being 605, and the smallest 52! In many cases, from 18 to 24 human beings are crowded and stifled for a whole night in small apartments, of the dimensions of 10½ to 11½ feet long, by 8½ to 9½ feet wide, and 6 or 7 feet high; whilst the lion, hippopotamus, and other wild animals, in Regent's Park Zoological Gardens, are accommodated with apartments of immense size, duly warmed and ventilated, with abundance of pure water, and all the other necessities of life.

The results of this state of things are well exemplified by an extract from the eighth report of the Registrar-General:—

*Mortality of Church Lane compared with other Districts of the Metropolis of London.*

| Of 100 children born, there die before arriving at 1 year old, | | Of 100 children aged 1 year, there die before they arrive at 2 years, | |
|---|---|---|---|
| In Church Lane, .......... | 31 | In Church Lane, .......... | 46 |
| In whole of St. Giles's, ... | 28 | In St. Giles's,.............. | 15 |
| In Lambeth, ................ | 20 | In Lambeth, ................ | 10 |
| In City of London,......... | 19 | In City of London,........ | 12 |
| In Islington, .. ............. | 16 | In Islington,................ | 7 |

Any remark upon these facts would be superfluous; they speak for themselves, and show the immense amount of human misery and death which is caused by ignorance and inattention to the physical causes of disease. The lesson to be derived from the above remarks ought now to be taken advantage of, by every one who has his own welfare and that of his fellow-mortals at heart. Every inhabited apartment ought to be well ventilated *at least once* in the course of the twenty-four hours; bed-rooms ought to have their windows open during the greater part of the day, and the bed-clothes spread out, so as to be thoroughly freed from the effluvia of the body, with which they have been impregnated during the night. A room without a fire should be more carefully ventilated than a room with a fire, which of itself acts as a ventilator, by causing a current of heated air to pass up the chimney, and a current of external air to come into the apartment. It follows as a consequence, clearly obvious from these observations, that the larger and loftier the room, the more pure and salubrious the air.

4. *Deficiency of light* may be classed as another atmospheric cause of disease. The light of the sun is absolutely necessary as well to animals as to plants, to enable the living structure to acquire and maintain that vital energy which is so effective a barrier against the inroads of disease. If a plant be confined in a dark place, it will soon lose its fresh, green hue, and although supplied with all the other requisites of health, with the exception of light, it will become sickly and blanched: give a ray of the sun admission into its place of confinement, and immediately it will begin to grow in that direction, exerting a natural effort, as it were, to get to the light. Light is equally indispensable to the health of the human body; people who inhabit dark dwellings, and are prevented, by their occupation, from enjoying the benefit of the sun-light—even with a due regard to a supply of pure air, good food, exercise, cleanliness, &c.—have a sickly appearance, and would much sooner fall victims to surrounding causes of disease, than if they could have availed themselves more of the light of the sun. Dwelling-houses ought, therefore, to have a sufficient number of large windows; and now that the tax upon *sun-light* is removed, and the duty on glass abrogated, we have no excuse, but an antiquated taste, for adopting the small, prison-looking slits of the Elizabethan style of architecture. The principal rooms of houses should always, as near as possible, face the sun at mid-day; and for this reason, also, the north side of a street, which runs east and west, should, for the sake of health, be chosen in preference to the south.

In making choice of a site for building a family residence, *four* things ought, in a sanitary point of view, to be strictly attended to in the climate of Great Britain:—1st, That it be thoroughly *dry;* 2d, That it be as *high* as possible, compatible with shelter; 3d, That it be well *sheltered* from the north and east; 4th, That it be not *overshadowed* by other buildings, hills, or woods, so as to deprive it of the full light of the sun at all seasons of the year.

"Numerous facts," says Dr. Carpenter,* "collected from different sources, lead to the belief that the healthy development of the human body, and the rapidity of its recovery from disease, are greatly influenced by the amount of light to which it has been exposed. It has been observed, on the one hand, that a remarkable freedom from deformity exists among nations who wear very little clothing; whilst, on the other, it appears certain that an unusual tendency to deformity is to be found among persons brought up in cellars, or mines, or in dark and narrow streets. Part of this difference is doubtless owing to the relative purity of the atmosphere in the former case, and the want of ventilation in the latter, but other instances might be quoted in which a marked variation presented itself under circumstances otherwise the same. Thus it has been stated by Sir A. Wylie (who was long at the head of the medical staff in the Russian army), that the cases of disease on the dark side of an extensive barrack at St. Petersburgh, have been uniformly, for many years, in the proportion of three to one, to those on the side exposed to strong light. And in one of the London hospitals, with a long range of frontage, looking nearly due north and south, it has been observed that residence in the south wards is much more conducive to the welfare of the patients, than in those on the north side of the building."

* Manual of Physiology, page 55.

## ASTRONOMY.

### CHAPTER III.

#### HISTORY AND PROGRESS OF ASTRONOMICAL DISCOVERY.

Among the many distinguished philosophers that render the 17th century remarkable in the history of literature, the name of Kepler will ever stand pre-eminent. Without detracting from the acknowledged merits of others, it may be safely asserted, that he did more to place the science of astronomy on a solid foundation, and to pave the way for the brilliant discoveries of future observers, than any other individual. To an unrivalled depth of genius, and to an ardent and enthusiastic imagination, were joined in him the most consummate industry and perseverance—qualities which are very rarely united in the same person.

Few great discoveries were ever achieved for which their authors could claim absolute originality; to the vague theory of some speculative mind, to some obscure hint, to some accidental circumstance, are we indebted for most of the discoveries in science. It was totally different with Kepler. For the discovery of his three remarkable laws, he was indebted to no theory but his own—to no hints, but those of an ever-active originality of mind—to no chance circumstance, but the extraordinary combination of rare mental qualities: the imperishable honour was all his own, and will redound to his immortal fame, when the very names of many whom we now look upon as men of genius shall be blotted out by the hand of time.

He was born near Weil, in the duchy of Wurtemberg, in December, 1571. His father was of noble birth, but, by an unfortunate occurrence, was reduced to poverty, and young Kepler was employed at servile labour till he reached the age of twelve years. By the kindness of the Duke of Wurtemberg, he was admitted, at the age of fourteen, to the school attached to the monastery of Maulbronn. In 1589 he was sent to the university of Tubingen, where he studied mathematics under the celebrated Maestlin, from whom, it is supposed, he imbibed his Copernican views of astronomy; and having acquired the degree of master of philosophy, he entered on the course of study necessary to qualify him for the priesthood. He completed his theological education, and entered on an ecclesiastical office; but the astronomical lectureship of Grätz, in Styria, having become vacant in 1594, he was offered this situation; and although he assures us, that so far from having devoted his attention to astronomy, he actually had an aversion to the science, yet he was induced, by the advice and persuasion of his tutors in the university, who doubtless understood and appreciated his talents, to accept the offer.

No sooner had he entered on his astronomical labours, than the heat and fervour of his imagination carried him headlong into the whirlpool of speculative and fanciful theories; and in 1596 he published his "Mysterium Cosmographicum"—

a work containing many ingenious, but, from their not being based on observation, most fanciful hypotheses, regarding the number, distance, and periodic times of the planets. He sent a copy of the work to Tycho Brahé, who had just settled in Bohemia, and whose judgment and intellect had been matured by thirty years of the closest observation of celestial phenomena. Tycho did not, as many inferior minds would have done, throw ridicule on the book, call it the delusion of a day-dreamer, and attempt to damp the ardour of its enthusiastic and youthful author; he had the sagacity and penetration to see through the mazes of unsupported theories with which it was filled, and to discover, in their development, the tracings of a brilliant genius, in whom the germs of unbounded perseverance, of unwearied and accurate calculation, and of the most ardent enthusiasm, only required a little careful culture to be productive of the most splendid fruits. He therefore wrote to Kepler in the kindest and most encouraging terms, urging him "first to lay a solid foundation for his views by actual observation, and then, by ascending from these, to strive to reach the causes of things."

Being involved in pecuniary difficulties by his marriage, in 1597, and annoyed by the religious warfare which distracted Styria, Kepler left Grätz in 1598, and took refuge in Hungary; and in 1600 he accepted a warm and pressing invitation from Tycho to join him at Prague, and assist him in his calculations. So poor was Kepler, that having been seized with ague on his journey thither, he was unable to defray his travelling expenses, much less to support himself after his arrival; and he was obliged to throw himself and his family for many months on the generosity of Tycho. The noble and benevolent Dane not only relieved all his wants, and gave him the benefit of his sound advice and experience, but also introduced him to the emperor. Rudolph appointed him imperial mathematician, with a liberal salary, on condition that he should assist Tycho in his calculations towards the construction of new astronomical tables, which were to be called Rudolphine, in honour of himself. It is to be regretted, that for these various and great marks of kindness and affection, the impetuosity and jealousy of Kepler's temper frequently prevented him from exhibiting that gratitude to his benefactor, which was so richly earned on the part of Tycho.

On the death of Tycho Brahé, in October, 1601, the task of constructing the Rudolphine tables devolved upon Kepler, who succeeded him as principal mathematician to the emperor, and who fell heir to his very extensive, accurate, and valuable store of astronomical observations. It so happened that, during the lifetime of Tycho, the part of the Rudolphine tables, on which Kepler was engaged, was the reduction of the extensive observations of the former relative to the planet Mars. That circumstance directed his attention in a peculiar manner to the orbit and motions of this planet; he long attempted in vain to represent its motions as observed by Tycho, on the hypothesis of a circular orbit; and after more than four years of laborious calculation, he was led to the irresistible conclusion that the orbit of Mars was *not* a perfect circle. Having made several fruitless efforts to confine the track of the planet to various other imaginary curves, he at length discovered that the orbit which the planet describes round the sun is of an *elliptic* or *oval* form, the sun occupying one of the *foci*.

The law which regulated the form of the orbit of Mars was found to bind the orbits, not only of all the primary planets, but of all their moons or secondaries. The *first* great law of Kepler, then, is thus expressed:—

*The planets move in elliptic orbits round the sun, which is fixed in the common focus of all their orbits.* (See fig. 6.)

Kepler at the same time discovered that Mars did not move round its orbit with a uniform velocity, as had hitherto been the universal opinion among astronomers; but that it moved much quicker at its *perigee*, or at the part of its orbit nearest the sun, than when at its *apogee*, or at its greatest distance from the sun. By patient and persevering calculation, he discovered that the times in which the planet moved over any two portions of its orbit, or *arcs* of its *ellipse*, are to one another as the areas included within lines drawn from the sun's centre to the extremities of these respective arcs; so that Kepler's *second* great law is thus technically expressed:—

*The line joining the sun and any planet (called the radius vector), in being carried along by that planet, passes over equal areas in equal times.* (See fig. 7.)

By these two laws were the cycles and epicycles of preceding astronomers banished for ever from the heavens, and the ancient doctrine of the circular orbits, and uniform velocities of the planets, completely abolished; by them also could the exact positions of the planets be calculated to any period *backward*, and their *future* positions and relations be predicted with the most unerring accuracy.

From the time that Kepler first began to study the heavens, he appears to have been strongly impressed with the idea that the celestial, as well as terrestrial bodies, were governed by fixed and immutable laws. This intuitive conviction seems to have supported him through seventeen long years of herculean mental toil. It was one of his first opinions connected with the mechanism of the solar system, that some relation existed between the distances of the planets from the sun, and the times of their revolutions round their orbits. Before he met with Tycho, he imagined that he had discovered this relation, and that it was truly represented by circles inscribed and circumscribed about the five regular geometrical solids. He afterwards set the planets to music—made one to take the treble, another the tenor, &c.; but as his mind became matured, he began to see that these fanciful theories were not corroborated by observation; and he at length learned to submit every one of his hypotheses to the most rigorous mathematical test, abandoning them, without the least hesitation or regret, whenever he discovered their fallacy.

Fig. 6.

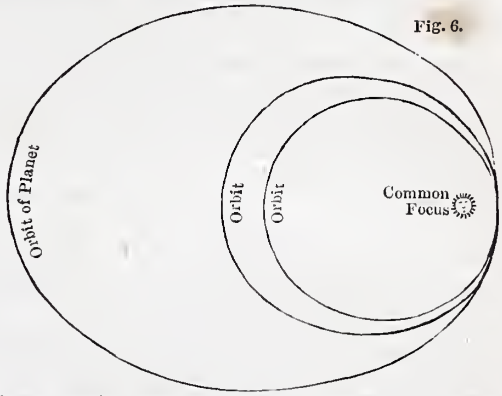
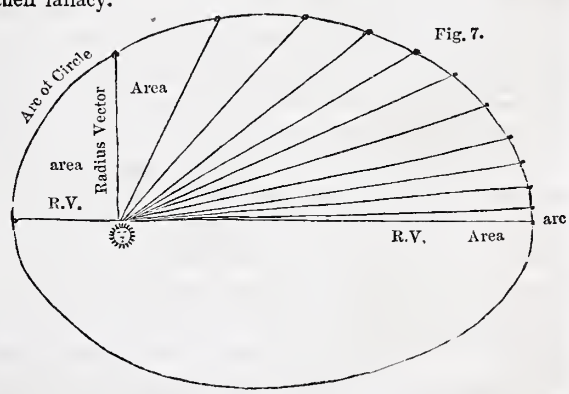



Fig. 7.




After spending seventeen years in search of what most men would have called a chimera—*the exact relation of the periodic times of the planets to their distances from the sun;* after undergoing an amount of mathematical calculation and mental drudgery quite unparalleled in the annals of literature—without the important aid of the *sextant*, which has

been aptly denominated a "portable observatory," or the assistance of *logarithms*, which, by a few lines of simple addition and subtraction, serve for sheets of complex calculations; and after scores of unsuccessful guesses, and thousands of calculations, to prove the falsehood of these guesses, Kepler finally reached the grand discovery of his *third* law:—

*The squares of the periods in which the planets perform their revolutions, are as the cubes of their mean distances from the sun.*

For example, the square of the period in which Jupiter performs his annual revolution, is to the square of Saturn's period as the cube of the mean distance of Jupiter from the sun to the cube of the mean distance of Saturn. The distance of one planet from the sun being known, therefore, and the periods of them all, the distances of all can be easily calculated by an arithmetical problem; or the period of one of them being known, and the distances of them all, the periods of all can, in the same way, be easily ascertained.

At this discovery, which stands in bold relief as one of the grandest and most important ever achieved by human industry and talent, the joy of Kepler knew no bounds. "Nothing holds me. I will indulge my sacred fury!" says he. "If you forgive me, I rejoice; if you are angry, I can bear it. The die is cast. The book is written, to be read either now or by posterity: I care not which. It may well wait a century for a reader, since God has waited six thousand years for an observer."

Kepler composed a work on optics, replete with new and interesting views, and gave the first idea of the telescope with two convex glasses, which has since been advantageously substituted for that of Galileo.*

In his famous work "On the motion of Mars," he thus explains the cause of the tides:—"If the earth ceased to attract its waters, the whole sea would mount up and unite itself with the moon. The sphere of the attracting force of the moon extends even to the earth, and draws the waters towards the torrid zone, so that they rise to the point which has the moon in the zenith." Hence, he argues, it is evident that the attractive power of the earth extends to the moon, and much farther.

This is certainly a near approximation to the discovery of *gravitation*. But he goes nearer still: for he asserts, that if two bodies of similar nature be placed near each other, but beyond the influence of a third body, they will attract each other like two magnets, each passing over a space reciprocally in proportion to its mass.

How melancholy to think that posthumous fame should be the only reward for such splendid and unwearied efforts in the cause of science! That a consciousness of the value of his labours, and of the importance of his discoveries, should have been his only consolation during thirty-five years of ardent devotion to the advancement of astronomy! Violently opposed and calumniated, on the one hand, by the Protestant clergy,† chiefly for adopting the new calendar as reformed by Pope Gregory XIII., in an almanac which he annually published as astronomer-royal; pressed and harassed, on the other hand, by pecuniary difficulties, in which he was constantly involved,—the life of Kepler was a life of misery. The peculiar circumstances of the emperor, Rudolph, prevented him from fulfilling his agreement with the astronomer as to the regular payment of his salary, as well as from defraying the expenses of completing and publishing the "Rudolphine tables;" and the consequence was, that the construction of the tables was indefinitely postponed; and Kepler was continually in such embarrassment for want of money, that he was obliged to write books for the subsistence of his family, and even to betake himself to astrology, with which his mind, it must be admitted, was always slightly tinged.

In 1624 he went to Vienna, and with some difficulty procured 6000 florins towards the completion of the astronomical tables; but it was not till 1627 that they made their appearance. They were the first that were calculated after the discovery of the elliptic orbits of the planets, and consequently by far the most correct that had ever appeared. Had Kepler, indeed, done nothing for the advancement of astronomical science but calculate these tables, he would have been entitled to rank among astronomers as one of the most persevering and indefatigable calculators that ever appeared.

In 1630 he exposed himself to the fatigue and vexation of a fruitless journey to Ratisbon, to obtain part of the arrears of his salary; and the result was, from annoyance and privation, that he fell a victim to a fever, which terminated his valuable life in that town, at the age of 59. "It is fortunate," it has been remarked, "that genius, like virtue, has its own reward. Had the progress of the human mind been intrusted to the generosity of princes, it might still have been struggling with the ignorance and prejudices of its savage state."

In this extraordinary age of discovery, while Kepler, a star of the first magnitude, illuminated the literary horizon of Germany, Italy boasted of the brilliant achievements of one of her sons, of the discoveries of the celebrated GALILEO —discoveries by no means so profound, nor the fruits of so strong a power of intellect, but more startling, because more obvious and comprehensible to uneducated minds.

Galileo was born at Pisa, in Tuscany, in 1564. He first studied the science of medicine, but soon relinquished it for that of mathematics, in which he speedily acquired such celebrity, that he was appointed to a mathematical professorship in the university of his native town, before he reached his 26th year. It was in the cathedral of Pisa that the idea struck him of measuring time by the pendulum, from observing that the vibrations of a lamp suspended from the roof were synchronous with the beats of his pulse.

The doctrines of Aristotle had, up to this period, reigned paramount in the schools of mechanical philosophy. To have dared to call in question any of the dogmas of the great master, in the mildest possible terms, would have been to incur the violent opposition and even the enmity of his disciples. Galileo was of a keen and irascible temper; he had a severe and sarcastic turn of mind, and apparently took pleasure in laughing his opponents to scorn. It need not, therefore, excite our surprise to learn, that by the supercilious manner in which he showed the fallacy of some of Aristotle's doctrines, and brought forward his own, he raised up such a host of public and private enemies, that he was obliged to leave Pisa in 1592, and accept of the mathematical chair at Padua.

He occupied the professorship at Padua for eighteen years; and during the greater part of this period he was busily engaged in advancing the sciences of mechanics and optics, for which his discoveries and improvements accomplished so much. In 1609, while on a visit to Venice, he learned by chance that a Dutchman of the name of Jansen had, by the aid of lenses, constructed an instrument by which distant objects could be seen nearly as distinctly as if close at hand. From the knowledge he possessed of optics, and of the properties of lenses, he was enabled on his return home to turn this information into such good account, that he constructed a telescope of his own. It consisted of a plano-convex object-glass, and a concave eye-glass, fixed at each end of a leaden tube of the proper length. Upon this first rude attempt he made many improvements, and at last succeeded in constructing a telescope which, according to his own account, magnified objects a thousand times, and represented them more than thirty times nearer to the eye of the observer. No sooner had he completed this instrument, than he immediately applied it to the examination of the heavenly bodies; so that, although the honour cannot be claimed for him of being the inventor of the telescope, he was undoubtedly the first to apply it to purposes of astronomical discovery.

With what mixed feelings of wonder, amazement, and delight, must the mind of Galileo have been filled, on his first examination of the orbs of heaven through his magical tube! The surface of the moon, analogous to our earth, covered with mountains, plains, and valleys—the planet

* Encyclopædia Britannica, Art. "Astronomy."
† Mechanism of the Heavens, by Professor Olmsted, page 295.

Jupiter attended by four satellites, or moons, revolving around him—the milky way made up of vast myriads of stars—several dark spots existing on the sun's surface, and carried round with that orb—the planet Venus revolving round the sun, and presenting phases at different parts of its orbit, like our moon—all burst in succession on the enraptured sight of the astronomer! These discoveries created a panic in the scientific world; and from Germany, from France, from Holland, and from England, were telescopes directed to the heavens, to falsify or corroborate the assertions of the Tuscan sage. The disciples of Aristotle were overwhelmed with horror and dismay; they felt the ground on which their system of philosophy was reared, to be tottering under their feet; and as most men become wedded to the opinions which they have learned in their youth, and very few can lay aside their preconceived notions, however erroneous, or look upon the advocate of opposite doctrines with feelings of complacency, it is not to be wondered at, that Galileo should have been looked upon by the schoolmen as their common enemy.

The fame of Galileo attracted the attention of Cosmo II., Grand Duke of Tuscany, and in 1611 he invited him to reoccupy the mathematical chair in the university of Pisa, to which he attached a very liberal salary. Galileo was subsequently raised to the rank of principal mathematician and philosopher to the Grand Duke, invited to Florence, and, to enable him to prosecute his researches, he was awarded a magnificent pension, and his time was to be left completely at his own disposal.

During a great portion of his life, Galileo was a stanch advocate of the Ptolemaic system of astronomy. About ten years before he constructed his telescope, he wrote a work on the sphere, in which he denominated the Copernican system a "solemn folly." It was not, indeed, till he reached the mature age of forty, that he became a convert to the new system, of which he soon grew a much more violent supporter than ever he had been an opponent. His telescopic discoveries contributed materially to strengthen his newly-adopted views; and he conceived, that the only barrier to their being generally acquiesced in, was the apparent variance between them and several passages of the Sacred Scriptures;—all denominations of Christians holding them to be totally irreconcilable, even the illustrious Tycho Brahé, as already mentioned, being among the number. To overcome this obstacle, Galileo endeavoured to explain away the Scripture difficulties by interpretations of his own; and, in 1615, his enemies denounced him to the Court of Inquisition at Rome, as a heretic, an unfaithful son of the church, and as one who held and taught doctrines contrary to the inspired writings. Galileo, however, was in great favour with several of the cardinals, and others high in authority at Rome, who admired and respected him as a man of genius and a philosopher; and this libel was so far from being entertained against him, that Caccini, a friar, was severely reprimanded, and, as is attested by Castelli—the friend and favourite pupil of the astronomer—the machinations of his enemies found no sympathy in the Eternal City.

In 1616, Galileo made his personal appearance in Rome, and, in the words of his friend Guicciardini, the Tuscan ambassador, "demanded that the Pope and the Holy Office should declare the Copernican system founded on the Bible: he wrote memorial after memorial: Paul V., wearied with his importunities, decreed that the controversy should be determined in a congregation."* This court saw no valid arguments to prove that his doctrine of the mobility of the earth, and stability of the sun, was a demonstrated truth; and, moreover, they considered it "*expressly contrary to the Sacred Scriptures, false*," in the sense of not proved, and "*at least erroneous in faith*;"† it, therefore, strictly and solemnly enjoined Galileo, neither to teach the doctrine, nor write concerning it, *except as a mathematician, and by way of hypothesis*. This injunction he faithfully and willingly promised to obey; and he wrote in triumph, on the day after the decision, to his friend, Picchena, that "the result has not been favourable to my enemies; the doctrine of Copernicus not having been declared heretical, but only as not consonant to the Holy Scriptures; whence the sole prohibition is of those works in which that consonance is maintained."

In 1623, Galileo made another journey to Rome, ostensibly to congratulate his friend Cardinal Barberini on his accession to the papal chair, under the title of Urban VIII.; but, in reality, to endeavour to win over the new Pope to his Copernican views, and to persuade him to declare them to be in accordance with holy writ. He was received by the Pontiff with the greatest cordiality and kindness, but he failed to accomplish his object—a circumstance by no means extraordinary, when the strongest argument he could produce in proof of the mobility of the earth, was his very erroneous opinion, that on no other supposition could the cause of the flux and reflux of the tides be explained—thus departing from the correct notion of preceding astronomers, the truth of which was well argued by his contemporary, Kepler, that they were caused by the attractive influence of the moon. He was, however, sent home to Tuscany, loaded with favours and presents, having also received a strong commendatory letter to Ferdinand II. de Medici, with the promise of a pension for himself and his son—a promise which was sacredly performed.

Soon after his arrival in Tuscany, Galileo commenced writing his celebrated work on the Ptolemaic and Copernican systems—a work professing to be "*Four days' Dialogues*" between two Copernicans and a Ptolemaist. It was published in 1632, and created a great sensation. He put into the mouth of the Ptolemaist, whom he called Simplicio, the same arguments which the Pope had used during his interviews with the astronomer, nine years previously, against the doctrine of the earth's mobility. He took every possible opportunity in this "Dialogue," to hold up the opinions of the Pontiff, as well as of all other Ptolemaists, to ridicule and derision. This was seized upon by the enemies of Galileo as a fit opportunity for poisoning the ear of his Holiness against the astronomer, by persuading him that a personal insult was offered, and that gratitude was outraged; it was, moreover, looked upon by the members of the Inquisition as an open and flagrant contempt of court, by his having, in the most glaring manner, violated the solemn injunction placed upon him in 1616: he was therefore cited to appear before them in 1633. Here Galileo was obliged to recant and abjure his doctrine of the mobility of the earth and stability of the sun, and was sentenced to be kept under the surveillance of the officers of the Inquisition for the rest of his life. Galileo, in writing an account to his friend, Father Banieri, of how this sentence of the Inquisition was carried into execution, says:—"After five months' sojourn at Rome (in the palace of the Tuscan ambassador), I was sent away at the time that the plague was ravaging Florence, and, with a generous pity, I was given for a prison the palace of the dearest friend I had at Sienna, Monsignor, the Archbishop of Piccolomini. My mind at this time enjoyed so much peace and happiness in his agreeable society, that it could return to its studies. It was then that I conceived and demonstrated the most part of my principles on the resistance of solids. Then the plague, with which my country was infected, having ceased at the end of five months, his Holiness condescended, at the beginning of December, 1633, to change the confinement of my residence for that freedom of the country which I loved so much."‡ He returned to his villa at Arcetri, about a mile from Florence, and spent the remainder of his days in advancing the sciences of astronomy and mechanical philosophy.

This final sentence of the Inquisition, Galileo appears to have brought entirely upon himself: first, by persisting in maintaining the absolute truth of the Copernican theory, before he had any demonstrative evidence to warrant the assertion; secondly, by prematurely condemning the old theory—which was then held to be supported by Scripture

* Despatch of 4th May, 1616. Marino Marini, "Memorie storicho-critiche," page 94.

† "Quia est expresse contraria Sacræ Scripturæ, et theologice considerata, ad minus erronea in fide."

‡ See Sir D. Brewster's Edinburgh Encyclopædia, Article "Galileo."

authority—and holding it up to ridicule and derision; and thirdly, by attempting to encroach upon the province of the theologian, and to alter the interpretation of certain passages of the Bible to suit his own views. The satellites of Jupiter were seen by the telescope to revolve around that planet, hence, it was argued by analogy, that the earth and all the other planets revolve round the sun: Venus was seen in phase at different parts of her orbit: and these were the sum total of the proofs adduced by Galileo, in support of the new theory, in addition to those of Copernicus himself, which, as we saw in last chapter, were far from being conclusive evidence in its favour. "No solid reason," says Delambre, "could be brought forward to induce mankind to disbelieve the evidence of their senses, previous to the voyage of Richer to Cayenne (1762), when he was obliged to shorten his pendulum; before Roëmer measured the velocity of light (1690), and Bradley had observed and calculated the phenomena of the aberration (1750). Previous to these discoveries, and that of universal gravitation by Newton, the most decided Copernicans were reduced to mere probabilities." *

On the subject of the persecution of Galileo by the Inquisition, there has perhaps been more misconception, and more misrepresentation, than on any other part of the history of literature—and this as well by Catholics as Protestants. Some writers violently condemn the conduct of the Roman ecclesiastics, and in their zeal to award Galileo a crown of martyrdom, and throw obloquy on the church of Rome, incur the charge both of falsifying history to forward their views, and of inconsistency, in refusing to allow that that church had any regard for the Bible, while at the same time they admit that it was to uphold the authority of Scripture that Galileo was condemned. Other writers exonerate the Papal authorities from all blame in the matter, and hold them infinitely less culpable than many of the divines of our own age and country, who strenuously opposed the truths of modern geology, on account of their apparent discordance with some of the historical parts of sacred writ. While a third class of writers, on a superficial inquiry, hastily but honestly condemn the Inquisition, and perpetuate the fictitious story of Galileo's torture, imprisonment, &c., but, on farther investigation, discover the errors they have been led into, and have the candour publicly to renounce them.† The truth is, that almost every scientific discovery which overturns the settled convictions and opinions of mankind, at first meets with opposition; and why should we suppose that the Copernican system of astronomy would have been an exception to the general rule—more particularly when the Ptolemaic system was interwoven in men's minds with the truths of Scripture? Was not the adoption of the calendar, as reformed by Pope Gregory XIII., opposed by every Protestant country, as dangerous to its faith and morals? Was not the old calendar used in England for more than two centuries, after its errors had been discovered and corrected by the Lateran Council at Rome, in 1516? Was not Des Cartes hunted down by the churchmen of Holland? Was not the immortal Harvey persecuted for maintaining the truth of his splendid discovery of the circulation of the blood? Did not Jenner meet with violent opposition in introducing vaccination—that inestimable boon to humanity? And even within a few years, was not a prejudice raised against the use of chloroform in easing the pangs of parturition, and this, too, on scriptural grounds?

That Galileo was endowed with high mental powers cannot be disputed; that he contributed vastly to the advancement of the sciences of mechanics and optics is well known; but it must also be confessed that his discoveries in astronomy "required only eyes, and may be regarded as following of course from the discovery of the telescope;"‡ so that the reason of his occupying such a conspicuous position among astronomers, is more the interest with which his biographers surround his persecution by the Papal authorities, for his strenuous advocacy of the Copernican system, than any great service he rendered to the science of astronomy.

In tracing the gradual development of astronomy down to the middle of the seventeenth century, we see it advancing step by step to assume its proper position among the sciences. Like the apparent course of the planets themselves, it sometimes stopped, sometimes even retrograded a little; at one time progressing with a slow, at another time with a quick motion; like them also its course was still onward towards the light of day. At the death of Galileo, in 1642, it had passed its midnight of darkness; the dawn of morn had appeared; but the sun had not yet arisen. Its cultivators had prosecuted the science with the most persevering ardour and enthusiasm; surrounded with the greatest difficulties, they had accomplished wonders; without the aid of logarithms to simplify their complex calculations; with few instruments, and those few very imperfect, they had recorded a vast store of accurate observations; they had made a number of important discoveries; they had propounded some beautiful theories, and, although these were as yet bare probabilities, their successors in the field of research had something tangible presented to their minds, on which their observations could be brought to bear. The exact form of the planetary orbits had been discovered; but why this form and no other? The planets were seen to move faster, the nearer they approached the sun in their course; but why? What invisible power did the Deity make use of to guide their motions? What kept them in their places? Whence all the splendid harmony of planets revolving around the sun, and satellites around the planet? It was affirmed by one party that the earth revolved around its axis in twenty-four hours, and round the sun in a year; but the other party demanded the proofs, and no demonstrative proof could be given. The answers to all these, and a thousand other questions, were as yet hidden in the sealed book of nature. To Huygens, to Cassini, to Roëmer, to Halley, to Newton, to Flamstead, to Bradley, to Euler, to Lacaille, to Herschel, and to Laplace—names imperishable in the history of the science—was the immortal honour reserved of penetrating the secret mysteries of the skies, of discovering the clue that was to unravel the intricate windings of the labyrinth, and of raising astronomy, from being the most vague, to the most certain of sciences.

To follow, in regular order, the discoveries of these and other celebrated men, who have essentially contributed to bring the science of astronomy to that state of perfection at which it has arrived, however interesting the task, would far exceed our limits in a work like the present; and we must, therefore, content ourselves by brief allusions to individual merits, as we proceed in treating of the special divisions of our subject.

## NEW METHOD OF PRESERVING TIMBER BY CREOSOTE.

The uses of timber are so numerous, and more especially in the great engineering operations of the present day, that any method strongly recommended for its effective preservation, might be expected to receive the benefit of a fair trial. It is, therefore, not a little remarkable, that even the different processes which have been generally known to the scientific world for some years, are seldom adopted in practice, and that although comparatively inexpensive, and calculated greatly to increase the durability, and therefore the value of the timber, they are rarely applied even in those cases where durability of material is one of the most important objects. The very parties who are most interested, seem to be those who take

* Astronom. Mod. Discours Preliminaire.

† "On the authority of many *distinguished writers*, we have stated, in our history of astronomy, that Galileo was thrown into solitary confinement. This, however, is a mistake, as there is abundant evidence to prove that he was merely threatened with confinement if he should refuse to acquiesce in the sentence of the Inquisition."—Sir D. Brewster's Edinburgh Encyclopædia, Article "Galileo," and Article "Copernicus." See also Professor Nichol's "Solar System," 2d Edition, page 27.

‡ Encyclopædia Britannica, Article "Galileo."

the least interest in this important subject, and each follows in the old beaten track, although by a slight deviation from it he might, by a small temporary outlay, find himself no inconsiderable gainer in the course of a few years. In the colliery districts, for instance, thousands of loads of timber are taken green from the forests and brought into immediate use, chiefly in the damp and heated atmosphere of the pits, where it is rotted and destroyed in a few months, whereas, if previously prepared by some efficient preservative process, it might, at comparatively small expense, be made to endure for several years. In railways, also, timber has hitherto been used for sleepers, generally without the slightest preparation, and the consequence is, that it soon decays, and requires frequent renewal. So sensible are engineers of this fact, and of the heavy expense thereby entailed, that the idea has lately been entertained of substituting iron sleepers for wooden ones, although it is acknowledged on all hands that those constructed of the latter material, are not only the most agreeable for travelling upon, but would, if rendered sufficiently durable, be also by far the most economical.

In the case of railways, we can easily account for the neglect of any general attention to this subject, from the haste with which they were run up, like a vast system of network over the country, so as to get them into working order in the shortest possible time, regardless, in many cases, of the actual permanence of the material; and perhaps, in general, practical men have been deterred from adopting the processes heretofore recommended, either from a lurking suspicion that they would prove ineffective, or that the advantages accruing from them in point of greater durability, would not be sufficient to compensate for the sacrifice involved in the immediate outlay. Perhaps there have hitherto existed some considerable grounds for these misgivings, and the consequent reluctance to adopt any of the processes recommended; but recently another method, invented by Mr. Bethell—that of preserving timber by means of bituminous oils combined with creosote—has been brought under the notice of our leading mechanical engineers—a method which seems to have perfectly succeeded so far as it has hitherto been applied, which has undergone the ordeal of several years' trial, apparently with complete success, and which therefore seems to be entitled to the serious attention of railway engineers, coal and iron proprietors, those engaged in the construction of harbour-works, and all who are extensively interested in the use of timber.

To understand the peculiar theoretical claims to superiority of Mr. Bethell's process, it is necessary briefly to explain the mechanical structure of wood, and the causes which, by a natural chemical action, lead inevitably to its decay and destruction, unless artificially preserved by the injection or application of some protecting substance. Wood is essentially a fibrous tissue, which, when examined with the microscope, is found to consist of longitudinal tubes, arranged in concentric rings around the centre pith, and these tubes vary in diameter from $\frac{1}{2000}$th up to $\frac{1}{200}$th part of an inch. By these tubes the sap is conveyed from the root to the branches of the growing tree, and after the tree is cut up for use, they contain the vegetable albumen—the chief constituent of the sap—a substance resembling, in its composition and appearance, the white of an egg. In the softer woods, the proportion of this substance averages one per cent.; in the harder it is less. The albumen is the insoluble part of the sap of vegetables. It is in this principle that putrefaction begins, and from which proceeds what is called the dry rot in timber. When putrefaction commences—and to this change the albumen has a great tendency—the woody fibre is soon infected, it becomes decomposed, and hence the speedy and entire destruction of the whole fabric.

To preserve the timber, it is therefore necessary to prevent the putrefaction of the albumen, and various plans have been proposed, with greater or less success, to accomplish this object, the chief aim of the authors being to coagulate that substance by means of metallic salts, and thus prevent putrefaction. Three of these methods may be mentioned as among the most successful:—First, there is Kyan's process, usually known as *kyanising*, which consists in the application of chloride of mercury; secondly, Burnett's process, by applying chloride of zinc, as a less costly substance; and, lastly, Payne's, by the use of sulphate of iron and muriate of lime, forming an insoluble precipitate in the pores of the wood. It must be admitted that serious objections have been found in practice to each of these plans. The metallic salts, when injected into timber in sufficient quantities to crystallize, must, in the process of crystallization, force open the pores, and this causes a disruption of the fibres, so that when the timber afterwards becomes wet, the crystals dissolve, and thus considerable spaces are left for the lodgment of water, which renders the timber much weaker, although from the presence of the salts it should be preserved from decay for some time. Again, the metallic salts do not absolutely seal the pores of the wood, and thus not only water but air is admitted, so that the fibre is still exposed to a process of oxidation—known in its effects by the term eremacausis—after the albumen has been precipitated. Lastly, all these processes involve the presence of acids, so that when iron is inserted in, or attached to any wood, previously subjected to one or other of the processes, the acids attack the iron, and rapidly hasten its destruction.

Mr. Bethell's method, which consists, as previously stated, of the application of bituminous oils, combined with a portion of creosote—a kindred substance, obtained along with the oils, by the distillation of coal-tar—does not appear to be liable to any of these objections, and seems, from a pretty long experience, to be quite effective. Creosote has long been well known to be powerfully antiseptic; it coagulates egg-albumen, although much diluted, and also coagulates serum. Its effect on animal substances is remarkable, and these, it is well known, are more liable to putrefaction than vegetable products. Meat and fish are preserved, after having been brushed over with it, and dried in the sun; and it appears to be the principle to which the antiseptic powers of wood-smoke and pyroligneous acid are due. It has been remarked, that three or four drops of creosote added to a pint of ink, which consists essentially of a vegetable principle, effectually prevent its mouldiness. These facts alone, which have long been well known, afford a strong *a priori* argument in favour of its probable efficiency, if ever applied as an agent for preserving timber. Its action, in combination with the bituminous oils, is thus described:—"When injected into a piece of wood, the creosote coagulates the albumen, thus preventing the putrefactive decomposition, and the bituminous oils enter the whole of the capillary tubes, encasing the woody fibre as with a shield, and closing up the whole of the pores, so as entirely to exclude both water and air; and these bituminous oils being insoluble in water, and unaffected by air, render the process applicable to any situation."

When Mr. Bethell first commenced his experiments, he found that by no amount of pressure could he get the creosote forced into the timber, from the presence of moisture in the pores, which, not admitting of compression, effectually resisted the admission of any other substance. He found it necessary, therefore, to adopt the obvious system of first drying the timber; and this was at first accomplished without the application of heat, when, after fourteen days, he found that the wood lost three pounds in every cubic foot. To accelerate the process, and render it more effective, he now uses a drying-house for this purpose, in which the products of combustion are passed through the timber, and by this means he finds that, in twelve or fourteen hours, the weight of Scotch sleepers, for instance, is reduced so much as eight pounds per cubic foot, and these can be made to absorb an equal weight of creosote. There are two methods in use by Mr. Bethell for impregnating the timber with this substance. One is by placing the wood in a strong iron cylinder, and exhausting the air from it by an air-pump, until there is a vacuum created equal to about twelve pounds on the square inch. A valve is then opened, by which the creosote is allowed to flow into the cylinder in this exhausted state, and by means of a force-pump a pressure is put upon it, equal to about ten atmospheres, or one hundred and fifty pounds, on the square inch. The timber is then taken out, and is fit for use.

By the other process, which is almost equally effective, and dispenses with the use of a steam-engine or pumps, the timber is placed in a drying-house, where, as previously stated, the products of combustion are passed through it, thereby not only rapidly drying the timber, but charging it to a certain extent with the volatile oily matter and creosote contained in the products given off from the fuel which is used to heat the house. When taken out of this house, the timber is at once immersed in hot creosote in an open tank, and left for some time to the natural process of absorption, without the application of any injecting force. By this means the timber is sufficiently impregnated with the creosote, speedily absorbing as much of that substance as it lost by weight in the drying-house.

We believe it is usual to weigh every piece of timber before putting it into the creosote tank, and again when taken out; and as a general rule, each piece is required to be increased in weight by the process ten pounds per cubic foot. This is the rule when the air-pump is employed, and in that case the quantity of oil used is found always rather to exceed the weight gained in the timber, on account of the loss of weight from the moisture extracted by the exhaustion of the air-pump.

It is a singular consequence of this process, that the most inferior timber, and that which would otherwise soonest decay, from being more porous, and containing more sap, or being cut too young, or at the wrong season, is thereby rendered the most durable. The porous wood absorbs a larger proportion of the preserving material than close and hard wood, and thus becomes in reality the harder wood of the two. It is found, for instance, that oak absorbs only half as much creosote as memel timber; and Mr. Bethell calculates, that common fir creosoted would last double the time of hard wood creosoted, because it absorbs more of the oil. Beech is found to make the best wood for the purpose, being full of very minute pores, so that a greater quantity of creosote can be injected into it than into any other wood, and in consequence of this it receives from the process a more uniform colour throughout. Long pieces of timber are found to require more time to saturate them in proportion to their length than shorter pieces—an apparent anomaly, which may, however, be explained from the fact, that the creosote appears to enter only at the ends, and to be forced up through the whole length of the pores. This operation must evidently require greater power, or longer time, after the creosote has penetrated farther up into the pores. The progress of the operation, when the forcing pump is used, is known by the quantity of creosote forced into the tank, after the latter was filled, in proportion to the number of cubic feet of timber contained in the tank.

This system of preserving timber, though not yet so extensively introduced as its manifest superiority seems to deserve, has, nevertheless, been tested on a scale sufficiently ample to prove, we think, in a most satisfactory manner, its perfect efficiency. It has been in use on several railways for some years past. About seventeen miles of the London and North-Western Railway have been laid with creosoted sleepers from nine to eleven years, and the engineer reports that, during that period, no instance has occurred in which any decay has been detected in them, and that they continue as sound as when first put down. Creosoted sleepers have also been laid for ten years on the Stockton and Darlington Railway, and still continue without the slightest appearance of any change or decay. On the Lancashire and Yorkshire Railway, creosoted timber has been used for five years as posts, paving blocks, &c., and we learn that while the upper part of the wood becomes very hard, the part under ground continues as fresh as when taken out of the creosote tank, though the timber employed was of an inferior quality. Indeed, it is one of the superior recommendations of this process, that engineers will thereby be enabled to use a cheaper timber with far greater advantage than they could use a more expensive timber uncreosoted. Take, for instance, the cost of a sleeper of American yellow pine at 4s., and one of Scotch fir at 3s.; to the latter add 1s. for creosoting, and the two will be the same cost; but the uncreosoted sleeper, although of the best quality of timber, would not last more than ten or twelve years, while the other would in all probability endure fully an average lifetime, if not for an indefinite period.

Some idea of the probable duration of timber thus preserved, or at least of the very protracted period for which it may be expected to resist the approach of decay, may be inferred from experiments commenced about twelve years since by Mr. Price of Gloucester, who placed different kinds of timber in the covers of a melon pit, where it was constantly exposed to the action of decomposing matter, as well as to the influence of the atmosphere. In this case the unprepared timber became decayed in one year, and required in a few years to be replaced; timber that had been kyanised lasted well for about seven years, but then gradually decayed; while creosoted timber, exposed in the same place, to the same influences, still continues as sound as when first put down twelve years since. And having resisted for so many years, without the slightest alteration, the combined operation of causes which reduced unprepared timber to dust in the course of two years, there is no reason to suppose that, under ordinary circumstances, timber so prepared may not continue in a sound and good state for even a century or more. This is a point on which it is impossible to speak with positive certainty, and which, if present expectations are realized, can only be decided by posterity; but when we consider the remarkable preservative powers of similar bituminous matters when applied to the animal structure, as evinced in the preservation of mummies for thousands of years, we are almost justified in drawing the inference that equally striking effects may be produced in regard to the preservation of wood, which is naturally less liable to decay than the animal frame. Indeed it was the mode of preserving mummies, which, according to his own statement, originally suggested to Mr. Bethell the use of creosote and bituminous oils for the preservation of timber. That gentleman states that any carcase of an animal put into a creosote tank assumes the precise appearance, and becomes in exactly the same condition, as a mummy.

Another advantage of the creosoting process is, that not only does it render the wood free from decay, but it is found that, when used for ship-building, harbours, docks, and other works contiguous to the sea, it effectually preserves it from the destructive attacks of the teredo worm. At Lowestoft harbour, where the plan is stated to have had an extensive trial for four years, this appears to have been proved in the most satisfactory manner. The superintendent reports that while there is no instance whatever of an uncreosoted pile being in a sound state, all being attacked by the limnoria and teredo to a great extent, and in many instances eaten quite through, there is, on the other hand, no case of a creosoted pile being touched, either by the teredo or limnoria; all are quite sound, though covered with vegetation, which generally attracts the teredo. A curious fact is mentioned by Mr. Bethell. One creosoted pile at Lowestoft, which had been half cut through for a mortice, but not filled up again, had really been attacked by a teredo, which had penetrated a little way into that part, but, finding the creosote disagreeable, had first turned to the right and then to the left, and still finding no relief, had ultimately quitted the timber without proceeding farther. The creosote is known to be destructive to all animal life, which renders the timber impregnated with it, whether on land or in water, proof against the attack of parasites; and it has this remarkable property, that, whether wet or dry, it remains intact in the timber; whereas, with the other processes in which metallic salts are used, these, in course of time, are washed out, or that portion which unites with, and coagulates, the albumen, is rendered innocuous to animal life by the new chemical union into which it thus enters.

We may add, that an average of 11½ lbs. of creosote per cubic foot is now put into all the memel timber at Leith harbour works, being forced in, to this large amount, by a pressure of not less than 180 lbs. per inch.

We have little doubt that the creosote process will soon be generally adopted for every description of work in which creosoted timber can be used with advantage. For harbour works, railway sleepers, &c., its value has been already acknowledged;

and we have no doubt that when the process becomes better known, creosoted timber will be used extensively, if not exclusively, for coal and iron pits, where it could not fail to be the means of proving an immediate economical benefit to the proprietors.

## THE ELECTROTYPE.

### CHAPTER IV.

#### ORIGIN AND HISTORY OF THE ART.

We have given, in three preceding chapters, a general and rapid outline of this remarkable art, both in practice and theory—an art which is not only one of the most recent, but likewise one of the most beautiful of all the modern applications of science to the uses and luxury of man. Chemistry itself, in all its vastness and magnitude, is yet but a new science. It has literally sprung into existence within the last century, and while it has already expanded into gigantic dimensions, and imparted a prodigious impulse to the progress of manufacturing industry in almost all its branches, it seems to be still on the threshold of a boundless field of discovery. Electro-metallurgy is only one of the small branches that have sprung from this prolific root within the last ten or twelve years, and yet it has already attained a degree of importance, and stretched itself over so extensive a field of application, that we must devote to it a more detailed elucidation than could be comprised within the limits of two or three short chapters. Having given, therefore, a general sketch of the art, in some of its leading principles, and more familiar processes, we now proceed to a more extensive view of it, beginning, first, with some account of its history, and then proceeding to explain the latest improvements, so as to fill up the short outline contained in the previous chapters. In this, as in other subjects, minute details will be found not only more useful, but generally much more interesting, than a condensed summary of leading principles.

It is remarkable that chemistry has rarely presented society with a discovery of importance in the practical arts, which has not been more the result of accidental observation—of unexpected fact, eliminated in the course of investigations undertaken for objects of a different nature—than of direct inquiry, instituted for the purpose of arriving at the discovery. This, indeed, is to be expected. Chemistry, unlike mathematics, is not a science of reasoning; it is a science of observation and deduction, founded upon experiment. The history of the accidental discoveries which have been made in it, would, in effect, be a history of at least the early part of the science, and of the whole round of the chemical arts and manufactures. The origin of electro-metallurgy is a case in point, and affords a remarkable confirmation of the doctrine, that no scientific fact is without its value.

Ever since the discovery by Volta, of the voltaic pile,—which is simply a multiplication of zinc and silver plates, separated by pieces of paper or cloth moistened in some saline or dilute acid solution,—the attention of the electro-chemist has been occupied with attempts to determine the arrangement best suited to produce, not only the most powerful, but likewise the most constant current of electricity by chemical means. The different modifications proposed, are nearly as numerous as the experimenters; but although the results are to this extent unsatisfactory, we are indebted to the investigations, undertaken with a view to the establishment of accurate data of arrangement, for many interesting, and, at the same time, practically useful discoveries, altogether apart from the direct object of inquiry. None of the least of these is the art of electro-metallurgy, which, notwithstanding its being a very recent addition to our practical knowledge, is familiar, at least in name, to every scientific reader.

It has also its literature; and some excellent treatises have appeared on the subject, among which we may mention Mr. Alfred Smee's "Elements of Electro-Metallurgy," Mr. Walker's "Electrotype Manipulation," and an admirable compend by Mr. Napier of Glasgow, which has lately been republished from the "Encyclopædia Metropolitana." These, and other works, contain much valuable information, but still, we think, they leave us some room for a few additional practical papers. We therefore proceed to give, in this chapter, a short account of the first discovery of the art, which, even at the risk of some repetition, we must introduce by explaining the distinguishing principle of Daniell's constant battery, and, with this view, we must briefly recur to the peculiar chemical action which leads to the development of electricity.

If a piece of metallic zinc be taken and immersed in water, acidulated with sulphuric or muriatic acid, the zinc, as stated in previous papers, is speedily dissolved; hydrogen gas is at the same time evolved from the decomposition of the water. This gas has a pungent smell, from the impurities in the metals employed. If pure metals were employed, this action of the acid would not proceed; but as pure metal cannot be obtained for ordinary use, the same effects in voltaic operations may be obtained, by taking the common zinc of commerce, after the acid has begun to act upon it, and rubbing a little mercury over its surfaces with a soft brush; the mercury combines with the zinc, and forms what is termed an amalgam upon its surface, or, in common language, the zinc plate is amalgamated.

If this amalgamated zinc be now put into the dilute acid, no action will be observed; if into the same acid solution be put a piece of clean copper, provided the metals do not touch, no more action is observed than if they were placed in as much water. But if we allow the copper and zinc to touch one another, either by the portions immersed, or out of the acid, hydrogen will be evolved from the surface of the copper, and that metal will appear being dissolved; but if the action be allowed to proceed for a short time, it will be observed, from the corrosion of the zinc, that it is that metal, and not the copper, that is being dissolved. If, instead of causing the two metals to touch each other, they be connected by a very fine platinum or steel wire, this wire will become red hot from some "substance," "agency," or "influence," which is passing from the copper through it to the zinc. This something is *electricity:* it is an electric current, which has in the first instance been generated by the action of the solution upon the zinc, and, having passed through the solution to the copper, passes from thence through the wire to the zinc again. These two metals thus arranged with the acid, constitute a galvanic battery of a single pair.

It was soon found by experience, that this kind of battery neither gives a long-continued nor a constant current of electricity, from the following causes:—First, the hydrogen is not freely evolved from the surface of the copper plate; and consequently, obstructing the influence of surface, affects materially the quantity of electricity obtained; and, secondly, a portion of the oxide, or chloride of zinc, formed by the action of the acid upon the amalgamated zinc, being reduced and carried along with the hydrogen to the copper plate upon which it is deposited, forms a zinc surface upon the copper, which tends to transmit a current of electricity in the contrary direction; and, consequently, to neutralize to some extent the original power of the circle.

Twenty years ago, these disadvantages were to a great extent overcome by a very ingenious arrangement, discovered by Professor Daniell. The discovery consists in the separation of the zinc from the copper by a porous diaphragm; the portion containing the zinc is charged with dilute acid as before, but the portion containing the copper is filled with a solution of sulphate of copper. The action in this battery is similar to that described above: the zinc is dissolved by the acid, but the hydrogen, instead of being evolved at the copper plate, combines with the acid of the sulphate of copper; the metallic copper is thus set at liberty, and combines with the copper plate, not only maintaining, but improving its surface, during the evolution of a constant current of electricity. During experiments with this form of battery, Professor Daniell observed, that the copper deposited, when separated from the plate, contained inverse impressions of scratches which had been previously upon the plate; but the object of the experimenter

had been fully attained, namely, the construction of a constant battery, and the practical applications of the phenomenon of deposition were overlooked.

At this point the matter rested for several years, till towards 1838, when Mr. Thomas Spencer of Liverpool, by a series of accidental circumstances, was led to think of the application of the decomposition of the copper, by electric action, to the multiplication of works of art—principally at first with a view to the formation of designs upon copper plates for printing—an idea from which has sprung the beautiful art of Glyphography.

The following paragraph from Mr. Spencer's paper, read before the Liverpool Polytechnic Institution, announcing the discovery, will convey some notion of the seemingly trifling circumstance from which has sprung the art of electrotyping:—

"The members of the society will recollect that, on the first evening it met, I read a paper upon the production of metallic veins in the crust of the earth, and that, among other specimens of cupreous crystallization which I produced on that occasion, I exhibited three coins—one wholly covered with metallic crystals, the others on one side only. It was used under the following circumstances:—When about to make the experiment, I had not a slip of copper at hand to form the negative end of my own arrangement; and as a good substitute, I took a penny and fastened it to one end of the wire, and put it in connection with a piece of zinc, in the apparatus described (a Daniell's battery). Voltaic action took place, and the copper coin became covered with a deposition of metal in a crystalline form. But when about to make another experiment, and being desirous of using the piece of wire used in the first instance, I pulled it off from the coin to which it was attached. In doing this, a piece of the deposited copper came off with it, and on examining the under portion, I found it contained an exact mould of a part of the head and letters of the coin, as smooth and sharp as the original on which it was deposited."—This may be considered the history of the first electrotype; but still, from the deposited metal being brittle, and other circumstances which probably had too much weight with Mr. Spencer, this electrotype, which ought to have been placed in the British Museum, was laid aside. Some time after this, Mr. Spencer accidentally dropping a little varnish upon a slip of copper which he was about to deposit, found that the deposit might be guided by such non-conducting substances over the surface; and finding also, by experience, that deposited metal is not necessarily brittle, but has its tenacity regulated by the electric current, thought of repeating the experiment with a coin in the same manner, that gave him the results just detailed. The result of this trial was a perfect electrotype. Being once successful, Mr. Spencer followed up his discovery with much vigour, surmounting many difficulties, and succeeded so far as to be able in a short time to furnish some excellent processes, by which medals and plates may be copied, and also means by which non-conducting substances, such as wood, wax, plaster, and the like materials, might also be coated.

We may mention here, that during the same time that Spencer was maturing his discovery so as to bring it before the public, Professor Jacobi of St. Petersburgh announced a similar discovery; and, as in many other instances, the merit of the first discovery of this art has consequently become a matter of dispute—both claiming precedence. From the evidence brought forward on the different sides, it would be a matter of some difficulty to decide to whom it most justly belongs. Indeed, it is now universally admitted, that there is a third party who was engaged with the same subject, and who was the first to make public, in this country, the method of operating and producing electrotypes. The facts of the case are, that in the beginning of May, 1839, the 'Athenæum' announced that Professor Jacobi had discovered a method of converting any line, engraved on copper, however fine, into a relief, by a galvanic process. In consequence of this announcement, Mr. Spencer, on the 8th of May, 1839, gave notice to the Liverpool Polytechnic Institution, that he should make a communication to them of his process for effecting results similar to those of Professor Jacobi. But Mr. Spencer appears to have changed his design of reading it to the above Institution, in order to have it read at the meeting of the British Association, which was to take place a short time after. But, from certain causes, Mr. Spencer's paper was not read to the Association, and was therefore read to the Liverpool Polytechnic Institution immediately after, as mentioned in the preceding details. Meanwhile the announcement of the 'Athenæum' was quoted in the 'London Mechanics' Magazine' for May 11th, 1839, which brought forth a letter from Mr. C. J. Jordan, a book-printer, dated 22d May, 1839, and published on the 8th June of the same year, in the 'London Mechanics' Magazine.' In this letter Mr. Jordan decribes his experiments upon the same subject, detailing the method of taking electrotypes, and offering hints which have since been acted upon with great advantage. The description coincides with that afterwards given by Mr. Spencer. But it is a strange fact, that among the many thousands who have taken a deep interest in the progress of electro-metallurgy, no one, not excepting the editor himself of the 'Mechanics' Magazine,' seems to have known of the existence of Mr. Jordan's letter, if we except Mr. Henry Dircks alone, who, in two contributions to the 'London Mechanics' Magazine,' dated January, and February, 1844, tells us he was aware of it from the time of its first publication. We cannot say much in favour of the policy of Mr. Dircks, or his love for scientific truth, who could remain silent for nearly five years, and see the righteous claims of Mr. Jordan, whose natural diffidence prevented him from bringing forward his own cause, set aside by every pretender to electro-metallurgy. Neither can we subscribe to the inference which Mr. Dircks draws from his papers, and say Mr. Spencer is a mere filcher of other men's good name. We are rather inclined to view it as an instance of the unity of intellectual perception in reference to the general principles of nature; and we think that Professor Jacobi, Mr. Jordan, and Mr. Spencer, had viewed the subject of electro depositions in the same light, and presented, according to their several abilities, the same subject, independent of each other.

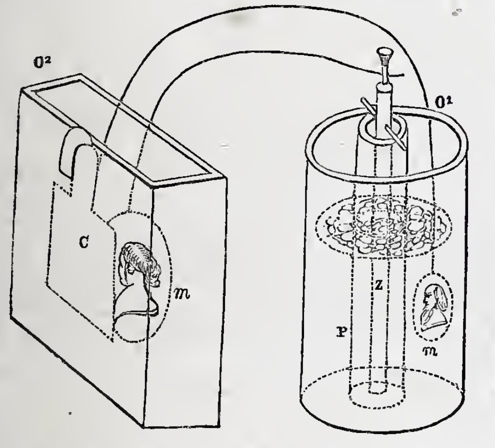
The publication of Mr. Spencer's discovery acted like an electric shock upon society, and men, both of science and art, became active competitors in this new field of application; the one class anxious to bear away the honours arising from some important improvement—the other, the profits which might follow some novel application of the process to their own, or some other branch of manufacture. With these combined efforts, it need not be wondered at, that in a very short time improvements of great scientific interest were pointed out, and applications of the greatest importance to the arts and manufactures of this country were introduced. In consequence, some of our old and standard manufactures, as we shall subsequently have occasion to notice at some length, have already begun to be revolutionized.

It may be necessary, in this historical sketch, to remark briefly those improvements which were introduced into electro-metallurgy by men of science. In general terms, these may be ranked under three heads: the first was the use of plumbago or black-lead, to give the surface of non-metallic bodies a conducting medium. This was the discovery of Mr. Murray, a gentleman of high attainments and unassuming manners, who communicated the process to the members of the Royal Institution orally. The Society of Arts afterwards awarded to Mr. Murray a silver medal, as an expression of their sense of the value of the discovery. This application at once freed electro-metallurgy from every bound; it was no longer necessary to use either metallic moulds, or moulds having metal reduced upon their surfaces by chemical means—which, according to the processes then known, was both a tedious and uncertain operation, and only applicable to certain substances. Plumbago possessed all the requisite properties: it was plentiful, and therefore cheap; easily applied, and equally effective for every substance on which the electrotypist desired to obtain a deposit, or which he could wish to cover with metal, either for useful or ornamental purposes.

The next improvement of much importance was made by

Mr. Mason, and consisted in the application of a separate battery. Previous to this discovery, what is termed the single cell process was the only one used. It consisted in simply attaching the article to be deposited upon by a wire to a piece of zinc, and immersing the one into dilute acid, and the other into a solution of the metal to be deposited. The two liquids being divided by a porous diaphragm, constituted, as has already been observed, a battery of a single cell; but, in this case, the whole electricity was expended within the cell to deposit the metal upon the mould. By Mr. Mason's discovery, the electricity generated in the cell could be made to do an equivalent of work in a separate cell as well,—making the original arrangement the generating cell or battery to the second cell. In this last was also a solution of a metal having in it a sheet of similar metal attached to the copper of the first, and the mould to be covered attached to the zinc of the first, as explained in our second chapter.

Properly speaking, this improvement consisted in causing a medal, in the act of being deposited, to serve as part of a battery for the deposition of another medal. The accompanying cut will render it intelligible to the reader. $o^2$, outer vessel filled with sulphate of copper; $o^1$, another vessel, with




P, a porous cell filled with dilute acid, in which is placed $z$, a zinc plate, which is connected by a wire with a medal, $m'$, in the second vessel charged with sulphate of copper. The medal, $m$, in the first cell, is connected by a wire to a piece of copper, $c$, in the second cell; the electricity passes from the zinc, $z$, to $m$, and by the wire to $c$, them to $m'$, and by the wire back to the zinc, $z$.

This process, with different forms of battery, will be described in detail in another part of these papers. It may, however, in the meantime, be remarked, that many improvements of a minor kind followed those enumerated; but the last, and probably the most important, in a manufacturing point of view, was introduced by Mr. Parkes of Birmingham, to whom electro-metallurgists are much indebted. Instead of using plumbago, which for large surfaces has many objections, he takes wax, or better, a mixture of wax and rosin, or such other mixture as may be preferred for moulds, and mixes with it a solution of phosphorus in sulphuret of carbon—about one ounce of the former to four of the latter. He then takes a solution of nitrate of silver, about one ounce of this salt to four gallons of water. After the mould is obtained, it is put into this solution of nitrate of silver (lunar caustic), and, in a few minutes, a thin film of silver is reduced upon its surface. The mould is then attached to the battery, and immersed in the copper solution; the deposit over every part of its surface is instantaneous, and does not grow over it, as is the case with plumbago. For coppering plastic terra cotta, wood, shells, flowers, leaves, and the like, the solution of phosphorus in sulphuret of carbon is admirably adapted. The article to be coated requires merely to be washed over with this solution, and immersed in the nitrate of silver solution; a thin film of the silver is immediately reduced upon its surface, and it is then ready to be put into the copper solution. We must, however, defer the more minute details, until we come to speak of the latest processes recommended.

The improvements here enumerated, in connection with the general law first pointed out by Mr. Spencer—and more fully developed and explained by Mr. Smee and other experimenters, and which will be described in order—constitute the art of electro-metallurgy.

As might have been expected, during the general excitement which prevailed at the commencement of electro-metallurgy, each aspirant, being actuated by different motives, viewed results in different lights. All the new results obtained, although isolated, were, in the hands of so many experimenters, soon reduced to a systematic whole. Honesty, we are sorry to add, did not uniformly characterise the progress of the art. The history, short as it is, is not wanting in instances of unjust appropriation of discoveries; or, viewing the progress of events in another light, we have instances of individuals becoming so engrossed with their own investigations, as to overlook the labours of others;—hurrying over a series of experiments, they write a history of the art, and lay claim to a goodly share of the discoveries. As an example, we quote the following from a host of others:—

"The laws regulating the reduction of all metals in different states, were first given in this work as the result of my own discoveries. By these we can *throw* down gold, silver, platinum, palladium, copper, iron, and almost all other metals in three states: namely, as a black powder, as a crystalline deposit, or as a flexible plate. These laws appear to me at once to raise the isolated facts known as the electrotype into a science, and to add electro-metallurgy as an auxiliary to the noble arts of this country."—*Smee's Electro-Metallurgy.*

These are broad claims, and as broadly asserted; but, happening to know somewhat intimately the history of electro-metallurgy, and to have read a certain fable about a crow in peacock-dress, we are naturally led to inquire into the magnitude of Mr. Smee's claims to our gratitude a little more particularly—not for the purpose of detracting from the merits of any individual who labours to advance the cause of science, but with the honest intent of giving to all their due rights; knowing also, that if such statements as are contained in the paragraph quoted were well-founded, it did not require the author to enumerate his claims so prominently. We think it no digression in a historical sketch, to trace how far these pretensions are just. The first in order is, the laws regulating the reduction of all metals.

"Law I.—The metals are invariably thrown down as a black powder, when the current of electricity is so strong, in relation to the strength of the solution, that hydrogen is evolved from the negative plate of the decomposition cell.

"Law II.—Every metal is thrown down in a crystalline state, when there is no evolution of gas from the negative plate, or no tendency thereto.

"Law III.—Metals are reduced in the reguline state, when the quantity of electricity, in relation to the strength of the solution, is insufficient to cause the production of hydrogen in the negative plate in the decomposition trough, and yet the quantity of electricity very nearly suffices to induce that phenomenon."

We will not here inquire whether these laws are strictly correct, as we may have occasion to examine the subject at length in one of our forthcoming papers, but will, in the meantime, simply see what Mr. Spencer says of these laws. In his original paper, announcing the discovery, eighteen months previous to the publication of Mr. Smee's work, there is the following paragraph:—

"I discovered that the solidity of the metallic deposition depended entirely on the weakness or intensity of the electro-chemical action, which I knew I had in my power to regulate at pleasure, by the thickness of the intervening wall of plaster-of-Paris, and by the coarseness or fineness of the material. I made three similar experiments, altering the texture and thickness each time, by which I ascertained, that, if the partitions were *thin* and *course*, the metallic depositions proceeded with great *rapidity*, but the crystals were friable and easily

separated; on the other hand, if I made them thicker and of a little finer material, the action was slower, but the metallic deposition was as solid and ductile as copper formed by the usual methods. Indeed, when the action was exceedingly slow, I have had a metallic deposition much harder than common sheet copper, but more brittle."

The identity of these laws requires no comment; and, comparing the circumstances of the one having nothing but the rude apparatus of a new-born art, suggested by himself, to that of the other, enjoying the advantages of eighteen months' improvements, Mr. Spencer is astonishingly correct.

The other claim in the paragraph, is being the father of the science of electro-metallurgy, and adding this science to the noble arts of this country. Unfortunately for the validity of this claim, patents had been previously taken out, both in this country and in France, for the application of it to the arts. Messrs. Elkington's patent for the application of the science to silvering and gilding—the most extensive application yet introduced—was published in full detail, and the manufacture was in extensive operation months before the publication of Mr. Smee's book.

We will not notice more of Mr. Smee's claims to discovery in this part of these papers, but must add, that the publication of his book gave an impulse to the study of electro-metallurgy. It is not only a goodly collection of the loose facts scattered throughout various periodicals, but contains, besides, a digest of a host of experiments made by himself, and these are very carefully and correctly detailed.

We may also observe, that a few months after the publication of Mr. Smee's work, Mr. Walker published a little manual upon electrotype manipulation, which, from its popular style and cheapness, did more to spread a knowledge of the art, and to attract the attention of all classes to it, than all the other publications put together.

Some extracts from this work appeared in our first two chapters, and we shall perhaps be further indebted to it in our subsequent progress.

## THE DISC ENGINE.

The great problem with improvers of the steam-engine, from the time of Watt to the present day, has been the invention of a rotatory engine, by which the alternate motion of the piston in opposite directions, and the consequent loss of power, might be avoided. It is obvious that a serious loss of power must arise from the effort required, at the commencement of each stroke, to move the piston, and the parts between it and the crank, from a state of rest; and again, to overcome the momentum which these parts have acquired at the termination of the stroke. The *vis inertiæ*, or the immobility when at rest and the impetus when in motion, is necessarily very considerable in such massive machinery, and the effort required to overcome it is totally expended on the machinery without imparting any addition to the rotatory or propulsive power of the engine. It becomes, as it were, latent in the machinery, and is so much power or fuel wasted.

At low velocities, indeed, the loss of power thus incurred, by the alternating motion of the piston, is not very considerable; and such is the simplicity of the movement, the facility of its construction, and its durability, that the cylinder and piston engine will probably always continue in use for many ordinary purposes. At high velocities, however, the loss of power is great, the momentum of the mass increasing as the square of the velocity; and when it is considered that the locomotive requires its piston to make, on the average, five times the number of strokes per minute that a stationary engine makes at its proper speed, and that steam engines, applied to drive the screw by direct action, make about four times the number, it will be seen that the momentum is multiplied in the one case about twenty-five, and in the other about sixteen times, in proportion to the respective masses. But the locomotive and screw—for which such high velocities are required—are two of the most important agents of the present day; and hence the obvious value of saving, if possible, the power which is at present wasted upon the engine. This waste or loss, arising from the vastly increased momentum at high velocities, is not a mere theoretical disadvantage, but is capable of practical measurement and demonstration from the circumstance, that for a given duty, or a given amount of work performed, the same locomotive, for instance, burns more fuel at a high than at a low speed.

A rotatory engine—if such an engine could be made—would evidently obviate this disadvantage; and many ingenious efforts have been made, and vast expenses incurred, in attempting to construct such an engine. This may be regarded as having taken the place of the exploded perpetual motion; and, hitherto, with nearly the same result as the pursuit of that unattainable object. Rotatory engines have indeed been constructed, but always with such disadvantages attending them, that, either from leakage or friction, or want of durability, or some of these evils combined, the engines, when tried by the fuel test, have been found a failure.

The only attempt at a deviation from the ordinary principle which has been attended with success is the disc engine. This is not, in the proper sense of the term, a rotatory engine, but it avoids the reciprocating motion of the piston, and seems to be attended with most of the advantages, while it avoids the defects, of the engines hitherto constructed on the purely rotatory principle. The problem involved in it is somewhat curious and complex, but we shall confine ourselves to such a popular description as may render its principle and mode of operation intelligible to the general reader.

In this engine, the vessel in which the piston moves is not a cylinder, but a hollow sphere, with two large opposite segments cut off. The piston, which is called a *disc*, from its peculiar form and movement, (and hence the name of the engine,) is fitted in this barrel-like vessel, in such a manner that its centre coincides with that of the sphere. It moves upon a ball-joint, or rather a ball is rigidly fixed into its centre, which moves freely in a socket. But the radius of the disc or piston being equal to that of the interior of the spherical vessel in which it moves, it is obvious that it cannot have any progressive motion like that of the ordinary piston. It corresponds to a great circle within the sphere, and therefore may revolve within it, upon its own centre, as far as the spherical surface extends, but cannot perform a movement of any other description. The movement which it actually performs is that of a boy's top when nearly exhausted, dipping successively to every point of the compass, so that the lower edge of the disc seems to proceed round the interior, although there is no actual rotation. The motion of the disc resembles that of a wave, each point in its circumference successively rising and falling, and seeming to perform a sweep round, although there is really no rotative or progressive motion. This peculiar action will be understood by referring to the diagram, fig. 1.

*a a* is the disc or piston, and *b b* the spherical vessel in which it moves, and in which the action of the steam is brought to bear upon it; *c* is a ball concentric with the axis *d*, and rigidly connected with both the axis and disc; *e e* and *f f* are two conical covers, whose bases are the ends, *h h*, of the vessel. The cones, it will be seen, are turned inward, and their apices are so formed as to constitute the socket or support in which the ball moves. In the disc there is a slit, as shown in fig. 2, and, passing through this slit, there is a partition in the engine extending from the outside to the ball. The partition prevents the disc from revolving parallel to its own plane. The only motion of which it is capable is oscillatory. Any point in its circumference, for instance, may be depressed, and if the finger is pressed on the circumference, and carried all round, each point in succession will descend, and the opposite point will rise till a full circuit will be performed. The ball and axis being firmly fixed in the disc, this oscillatory motion of the latter will cause the extremity of the axis, *g*, to describe a circle, which may be regarded as the base of a cone, round which the axis revolves, and thus, by the oscillatory motion of the disc, a rotatory

motion is directly communicated to the crank in which the axis is fitted. To produce this motion, a passage for the admission of steam is made in the conical covers on one side of the partition, and a similar passage for the exit on the other side of the partition. The result is, that the steam enters on one side of the partition, sweeps like a wave round the disc, and escapes on the other side of the partition. It is obvious that the corresponding apertures made in the other cone, on the other side of the disc, will double the power of the engine. Thus a revolving wave is produced, and a consequent continuous rotation of the crank axis, by which we may communicate motion to any system of machinery.

The principal difficulty in the construction of this engine is, to render the various points of contact between the disc and other parts steam-tight. The latter must rub or slide up and down against the partition, and against the interior of the sphere, and these parts must be steam-tight. The contact of the ball with the conical cover, through which the axis passes, must likewise be steam-tight; and, finally, the disc, in pressing successively against the cones with every point of its surface, must also be steam-tight at each radius of contact. From the following rapid historic sketch, it will be seen that the successive improvements in this engine have chiefly consisted in devices for effecting these objects.

Dakeyne took a patent for the disc engine in 1830, and seems to have been the first inventor, although it is believed that the merit of independent discovery must also be allowed to Davies, of whose subsequent improvements we shall speak immediately. Dakeyne's engine resembled the design in fig. 1, the axis being carried through only one of the covers. The central ball was made hollow, and a spherical pin or pivot on which it moved was fitted to the apex of the cone farthest from the crank. This engine, we believe, was never brought into practical operation.

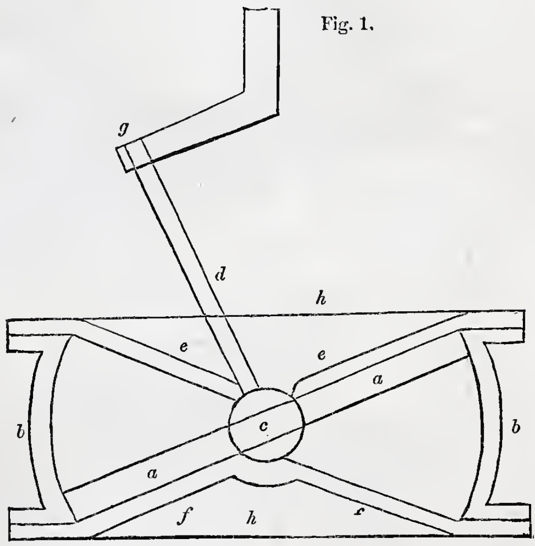
Henry Davies, to whom we have just alluded, was the next and probably an independent inventor. He began by taking a patent for the disc engine of Dakeyne, and, in the specification, he adopts Dakeyne's idea of the cones and partition; but, by making the disc axis work in a bearing forming an angle with those of another axis which carries the spherical vessel, he causes the whole to revolve—both the vessel and the axis. In Dakeyne's engine, the contact between the smooth surfaces of the cone and disc was the only means by which the steam was prevented from escaping between the two. To obviate this imperfection, Davies took out another patent, in which the respective surfaces of the disc and the cones were formed with teeth falling into each other, and radiating from the ball outwards. These engines performed remarkably well, and attracted great attention. But in 1840, Davies took another patent, in which the spherical vessel was again fixed, and Dakeyne's oscillating motion of the disc restored—retaining, however, the improvement of the toothed form, and adopting a better method of packing, so as to render the engine steam-tight round the central ball.

The proper packing of the ball is a somewhat difficult problem, in consequence of the confined space in which it is permitted to move. This will be understood when we state, that the surface of the ball is occupied by the disc, the axis, and two packings between these, (one for each cone,) while, at the same time, a sufficient part of its surface must be left open to allow of a free motion between the fixed parts. For this purpose the packing round the apertures for the axis must be conical, and the difficulty to be overcome is to render the conical packing such that it may not only adapt itself to the large end or base of the cone, but likewise admit of being compressed into the smaller end of the frustrum adjoining the ball. For this purpose, instead of using a conical packing of one piece, Davies cut into a number of segments of equal size a cylinder of packing, equal to the smaller end of the cone, and divided the interior surface of the conical opening into a number of parallel curved mortices, which, approaching each other toward the smaller end, met before they reached the ball. By this contrivance, the packing, though in detached pieces, became one solid mass round the ball, and admitted of being pressed together from without, as it wore down by friction.

But these were not the only improvements which Davies effected. The slit in the disc had hitherto remained open, or at least had not been made steam-tight with the partition. Indeed, in Dakeyne's engine a contrivance had been made for preventing the disc from rubbing against the partition in moving up and down. The steam, therefore, when it entered on one side of the disc, passed through to the other, and this prevented it from bearing upon the disc with its full expansive action. In the ordinary piston engine, the piston nearly touches the end of the cylinder, and therefore when the steam enters there is no cavity to fill before its expansive action is brought into play. In the disc engine it was different, while there was a passage for the steam between the disc and the partition. The cavity was first to be partially filled at the commencement of each stroke, and the force of the filling-up steam was lost. To obviate this defect, Davies took a patent in 1844 for farther improvements, by which he made the engine capable of acting expansively. He fitted the sides of the slit with metallic packing, making them work against the sides of the partition, and thus the high steam, having no cavity to fill, began by exerting its full force on the disc.

The latest improvements of this peculiar modification of the steam engine, by which the principle appears to have been brought to the highest degree of perfection of which it is capable, are due to the inventive ingenuity of Mr. G. D. Bishopp, aided by the admirable execution of Messrs. Rennie, Whitworth, Donkin, and other eminent engineering firms. With these improvements, the superior economy of the disc engine, as regards the consumption of fuel, seems to be sufficiently established, and if so, it possesses other advantages which cannot fail to recommend it, for several important purposes, to general use.

Fig. 1.




The two accompanying diagrams (figs. 3 and 4) illustrate the principal features of Mr. Bishopp's improvements, and exhibit the engine in its finished state, and as now in practical operation. The first is a section of the engine drawn to scale, and the second is a representation of a model in its position in a vessel, as shown in the Great Exhibition, Class II., No. 52. With the aid of these illustrations, we shall give a short account of the latest improvements, which constitute the principal features of novelty in Mr. Bishopp's claim. These are—

1st. The dispensing with the teeth in the cones, and substituting radial strips of metallic packing forced outwards by springs.

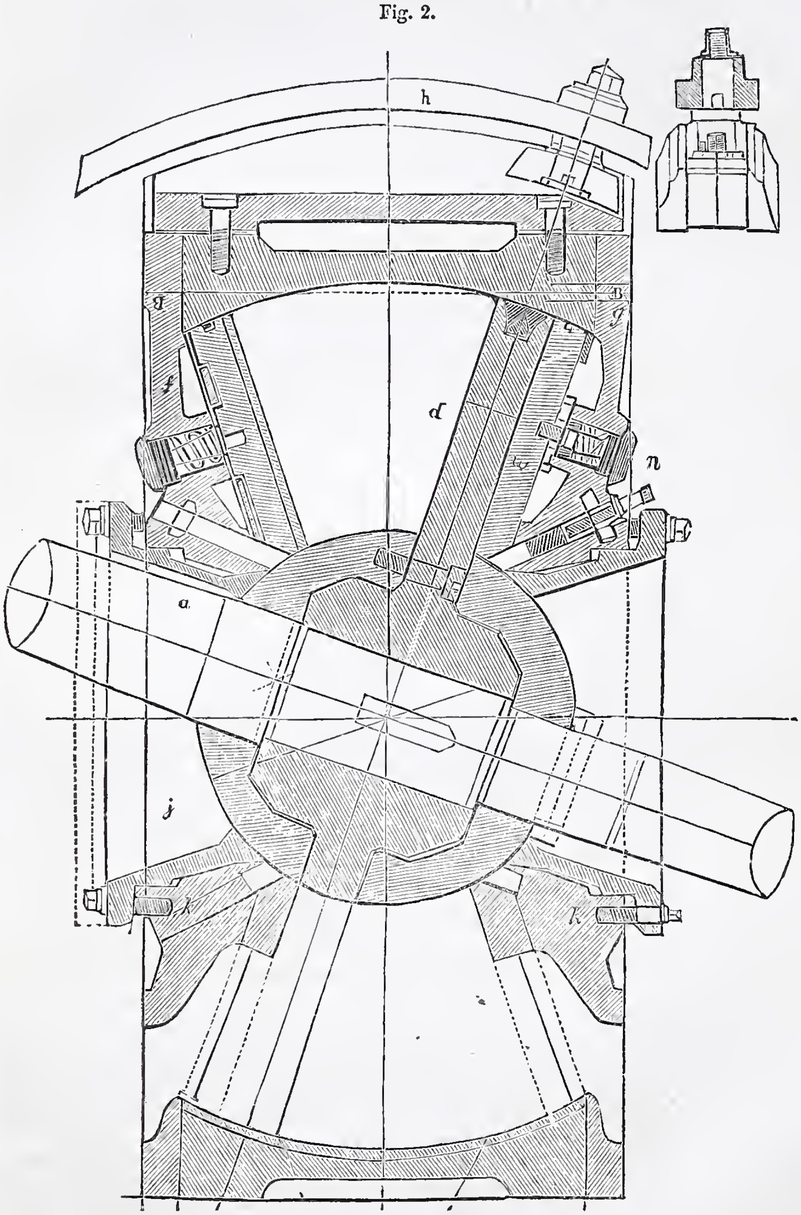
2d. Improved method of packing the disc round its periphery.

3d. Constructing the central sphere in two pieces, and not solid with the disc.

4th. The use of a guiding-bow (see fig. 4) outside, to keep the sides of the slit in the disc in proper contact with the sides of the partition.

With regard to the first peculiarity, it constitutes a very great improvement by rendering the surface of contact, beween the cone and the disc, as perfectly steam-tight as possible. To effect this with the toothed form required very superior workmanship in the first instance, and then the outer parts of the cone and disc were liable to more rapid wear than the parts nearer the centre, in consequence of the momentum of action being greatest near the circumference. Mr. Bishopp, therefore, dispensed with the teeth, and introduced into each cone a circle of metallic radial packings, fitted into grooves accurately planed for their reception. These packings, which radiate from the centre, are forced outward against the disc by springs, and are placed so close to each other round the cones, that the disc, on being depressed at any given point, comes in contact with two or three of them. The steam is thus intercepted without the necessity of contact between the disc and cones, the springs allowing the packings slightly to yield. In fig. 3, *m m* represent these packings, and *n n* the spiral springs to force them outwards. By proper arrangements they are not permitted to rise out of their respective grooves beyond a certain limit.

Fig. 2.



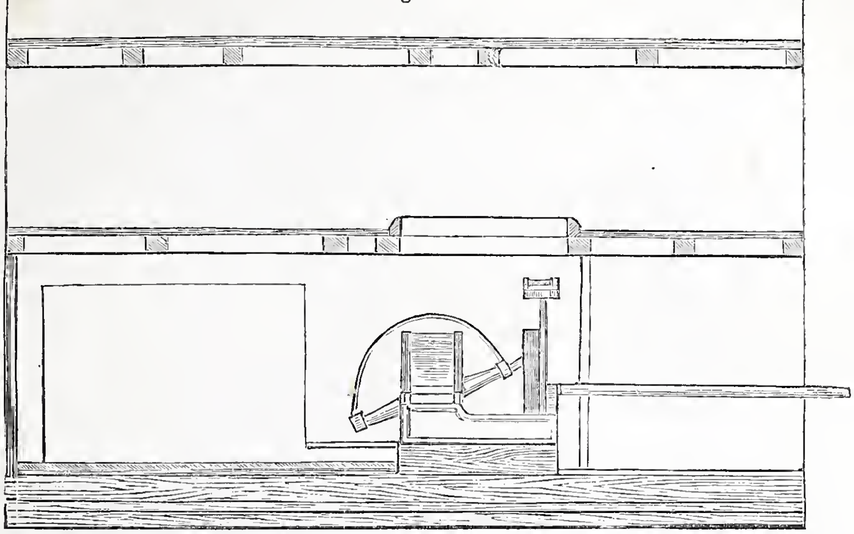

The second peculiarity which we have stated as due to Mr. Bishopp, is an improved method of packing the disc, *d*, round its periphery. It cannot be packed like a common metallic piston, for, in that case, the two thicknesses of metal, between which the metallic segments act, would involve the necessity of leaving spaces equal to their respective thicknesses unpacked, and this would occasion a constant leakage of steam. Mr. Bishopp, therefore, adopts the following plan:—He makes his packing of three cast-iron rings, which fit into a wedge-shaped recess or groove round the circumference of the disc. These rings are triangular in their cross section, as shown in the figure at *p*, and two of them are in contact with the inner surface of the sphere, while the third is inserted between them, and acts like an elastic wedge, pressing them both against the sphere and the disc, so as to compensate for wear.

Mr. Bishopp's third improvement consists in constructing the ball in two pieces, and not solid with the disc. The manner of this construction is likewise shown in the figure. It has the effect of insuring greater soundness in the ball, it being found that, when the substance of a casting is unequally distributed, the larger masses are subject to have air-bubbles remaining in the metal, which necessarily renders them unsound. The turning of the ball, with the disc attached, was also found an operation of great difficulty. But by turning separately the parts, *l*, the true spherical form is more easily produced, and the castings have also the advantage of being sound; besides that, by this mode of construction, the parts admit of being again made spherical when worn, by introducing a thin ring between the hemispheres and the face of the disc, and cutting the surface again to its true spherical form.

The next and last improvement which calls for special notice, is the use of a guiding-bow, to cause the packings of the disc to press steadily against the faces of the partition. This bow is shown in fig. 4, and partially in fig. 3, at *h* and *i*. Dakeyne, as has been already stated, expressly constructed his engine so that the sides of the slit in the disc should not touch the sides of the partition. This occasioned a constant leakage of steam, and there was always a large cavity to be filled before the expansive action of the steam could be brought to bear upon the disc. But the use of expansive steam is the greatest improvement which has been made in modern times in economizing fuel; and hence the importance of Mr. Davies' improvement, by which the sides

of the slit were made to rub against the partition. To secure a perfect action between the sides and the partition, Mr. Bishopp restored the semicircular bow which Dakeyne had used for keeping them separate from each other. The bow, as shown in fig. 4, is carried from two points on the axis, and over the engine. It carries a pin, on which is fitted a

Fig. 3.

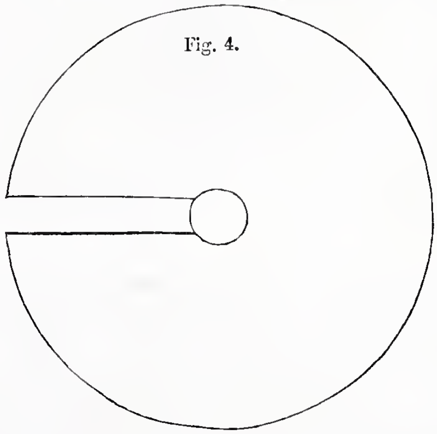


rectangular brass, *i*, (fig. 3,) which works in a groove on the top of the engine, coinciding with the plane of the partition. By this means the centre of the slit is made always to work in the same plane, and the packing presses steadily against the faces of the partition.

We have stated that these engines are no longer experimental. They have been adopted in numerous cases, and are said to have been found both economical and durable. Their economy in fuel is, we understand, satisfactorily confirmed at the *Times* printing-office, where Applegath's vertical printing machine is worked by one of Mr. Bishopp's engines of 10 horse power. In other cases, in which the engine has been tried, we believe the results have been the same.

The model disc engine (fig. 4) was exhibited by Messrs. Rennie, in Class V., No. 52, of the Great Exhibition, and is shown fixed in a model section of the hull of a merchant screw-vessel. The model of the engine and vessel was made on a scale one-fifth of the intended practical size. Expanded to their full dimensions, the measurement of the vessel would be about 300 tons, and the engine of 40 horse power. The engine would occupy 20 feet of the length, and 10 of the width. Coal-bunkers would surround the boiler, and the hold for goods would extend along each side of the engine, a deck being carried over the whole. It is estimated that a disc engine, in a screw-vessel, weighing (exclusive of boiler) 10 tons, would be of equal power to the 60 horse engines of a vessel which weighed, including water in boiler, 34 tons. This peculiar modification of the steam engine seems, therefore, to be well adapted to vessels propelled by the screw.

Fig. 4.



## COAL FIELDS OF GREAT BRITAIN.

### CHAPTER V.

UNDER-MARINE SERIES OF THE BASIN OF THE CLYDE.

We now proceed to the consideration of the earliest deposits of the coal formation, which we have attempted to describe in the previous numbers. The upper portion of the series consists chiefly of different groups of clay ironstones imbedded in shale; these groups, where their development has been ascertained, are separated by beds of sandstone, faiky shale, and limestone; and in one instance, with a coal bed of indifferent quality. There are four distinct groups of ironstone in the section, ascertained by the shafts and borings of the Nitshill Iron Company, near Hurlet. The number of ironstone layers amount in that locality to sixty-four—some of which are presently wrought by Mr. Dixon for the supply of the Govan Iron Works. The strata in which they occur form a section of 120 fathoms or more; a depth which it was proposed to sink to by the abovementioned company, in order to work the Hurlet coal—an attempt which was wisely abandoned. The pit, however, was sunk to a great depth, and afforded a better opportunity of satisfying the geologist as to the nature and extent of this portion of the stratification of our coal formation, as well as the nature of its organic contents, than any that has hitherto been offered. The principal organic remains were the producta scotica, and a great abundance of small spiriferæ and other marine shells. These occur principally in the shales, but they were also to be met with in the ironstone. The pit commenced in what may be considered the lower portion of the strata described in the last article; and after it had been sunk through several beds of sandstone shale, &c., a bore was made to strata, known by the name of Hosie's limestone, between which, and the Hurlet limestone and coal, there are about twenty beds of ironstone, as ascertained in the Hurlet pits.

The following is a section of a bore made in Victoria pit, Nitshill:—

| | ft. | in. | | ft. | in. |
|---|---|---|---|---|---|
| Plies of Sandstone, | 9 | 0 | Shale, | 2 | 5 |
| Freestone, | 19 | 0 | Ironstone, | 0 | 1 |
| Shale, | 16 | 3 | Shale, | 0 | 4 |
| Ironstone, | 0 | 6½ | Ironstone, | 0 | 3½ |
| Shale, | 0 | 11 | Shale, | 1 | 7 |
| Ironstone, | 0 | 3 | Ironstone, | 0 | 2½ |
| Shale, | 18 | 3 | Shale, | 3 | 3½ |
| Ironstone, | 0 | 3 | Ironstone, | 0 | 2½ |
| Shale, | 11 | 11 | Shale, | 1 | 8½ |
| Ironstone, | 0 | 4 | Ironstone, | 0 | 1½ |
| Shale, | 1 | 3 | Shale, | 1 | 4 |
| Ironstone, | 0 | 3 | Ironstone, | 0 | 2½ |
| Shale, | 8 | 2 | Shale, | 0 | 2 |
| Ironstone, | 0 | 2 | Ironstone, | 0 | 3 |
| Shale, | 16 | 0 | Shale, | 1 | 5 |
| Ironstone, | 0 | 2 | Ironstone, | 0 | 4½ |
| Shale, | 15 | 7 | Shale, | 0 | 5 |
| Ironstone, | 0 | 2½ | Ironstone, | 0 | 2 |
| Shale, | 10 | 0 | Shale, | 0 | 4 |
| Limestone, | 0 | 9 | Ironstone, | 0 | 1 |
| Shale, | 4 | 3 | Shale, | 3 | 0 |
| Ironstone, | 0 | 1½ | Ironstone, | 0 | 4 |
| Shale, | 0 | 10 | Shale, | 0 | 1 |
| Ironstone, | 0 | 2½ | Ironstone, | 2 | 6 |
| Shale, | 0 | 6 | Shale, | 1 | 0 |
| Ironstone, | 0 | 3 | Ironstone, | 0 | 1 |
| Shale, | 5 | 5 | Shale, | 6 | 1 |
| Limestone, | 2 | 0 | Ironstone, | 0 | 4 |
| Shale, | 1 | 9 | Shale, | 7 | 1 |
| Limestone, | 0 | 5 | Freestone, | 0 | 6 |
| Shale, | 0 | 7 | Shale, | 17 | 11 |
| Ironstone, | 0 | 1 | Ironstone, | 0 | 2½ |
| Shale, | 6 | 5 | Shale, | 2 | 5 |
| Ironstone, | 0 | 3½ | Ironstone, | 0 | 2 |
| Shale, | 2 | 6 | Shale, | 13 | 10 |
| Sandstone, | 0 | 7 | Ironstone, | 0 | 1 |
| Shale, | 0 | 2 | Shale, | 1 | 8 |
| Freestone and plies, | 24 | 5 | Ironstone, | 0 | 2 |
| Shale, | 0 | 10 | Shale, | 1 | 8 |
| Coal, | 3 | 0 | Ironstone, | 0 | 1 |
| Shale, | 7 | 8 | Shale, | 3 | 5 |
| Sandstone, | 0 | 7 | Ironstone, | 1 | 0 |
| Shale and Ironstone, | 23 | 5 | Shale, | 0 | 11 |
| Kingle and lime, | 1 | 4 | Ironstone, | 0 | 1 |
| Shale, | 20 | 0 | Shale, | 0 | 2 |
| Sandstone and plies, | 73 | 11 | Limestone, | 0 | 2 |
| Ironstone, | 0 | 2½ | Shale, | 9 | 3 |
| Shale, | 3 | 2½ | Ironstone, | 0 | 1 |
| Ironstone, | 0 | 3 | Shale, | 11 | 11½ |
| Shale, | 0 | 6 | Ironstone, | 0 | 3 |
| Ironstone, | 0 | 4½ | Shale, | 6 | 0 |
| Shale, | 1 | 6 | Limestone, | 1 | 5 |
| Ironstone, | 0 | 1 | Shale, | 1 | 2 |
| Shale, | 3 | 10 | Limestone, | 0 | 3 |
| Ironstone, | 0 | 6 | Shale, | 1 | 6 |
| Shale, | 1 | 6 | Limestone, | 0 | 10 |
| Ironstone, | 0 | 2 | Shale. | 0 | 10 |
| Limestone, | 0 | 10 | Sulphurous clay shale, 0 to 18 inches | | |
| Shale, containing 20 ironstone beds, | 20 fathoms. | | Coal, 5 to 8 feet, containing much iron pyrites. | | |
| Limestone, | 4 | 6 | | | |

The above section may well set the fears of the people of Scotland at rest, as to the termination of a supply of ironstone. No district, perhaps, is so stored with this invaluable mineral as the west of Scotland. It is true many of the bands enumerated are too thin to be wrought profitably; and that while there is an abundance of blackband ironstone to be had, even those which might be wrought will scarcely be sought after; yet, as the blackbands will, in all probability, become exhausted during the present century, it is consoling to the lover of his country, that there is an almost inexhaustible store of clay ironstones spread over very extensive areas, not only in the district described, but through many places in Ayrshire, and other counties. The localities where these ironstones are to be seen, are Hurlet and Nitshill, Blackhall near Paisley, Jordanhill, Duntocher, and in a burn near Canniesburgh toll. They occur also near Eaglesham, at Crossbasket and Crutherland—on the Avon between Glassford mill and Strathaven, and Fiddler's Burn, Raysgill and other places in the neighbourhood of Carluke. The deposit may therefore be considered as extending under the beds formerly described, for at least twenty miles in one direction, and thirty in another. It is not to be supposed however, that they are equally numerous in all these places. On the other hand, we rarely meet with more than 7 or 8 bands exposed to view. The ironstones are generally very similar in quality and appearance, and contain from 28 to 35 per cent. of metallic iron, and from 4 to 14 per cent. of clay; and occasionally a little manganese. The only places where they are wrought at present are, Carluke, for the supply of the Castlehill and Coltness iron works, which are also supplied with blackband from the parish of Whitburn; Crossbasket by the Clyde Iron Company; and as formerly mentioned, by Mr Dixon at Hurlet. The nearest place to Glasgow where they occur, is at White Inch, about two miles from the Broomielaw; where there is a very valuable field of them, not less than 2 feet 10 inches, lying so contiguous, as to be workable in one winning.

The limestone belonging to the series which principally claims our attention is, the bed wrought at Hurlet on the south; and Duntocher, Long Faulds, and Campsie, on the north of the Clyde, where it stretches for many miles alongside the trap range of Campsie and Kilpatrick. It varies from four and a half to six feet in thickness at those places, and is almost always attended by a coal equally thick, with an intervening layer of aluminous shale, from which the alum works of Hurlet and Campsie are supplied. It is of a light slate grey colour, and is rather granular, and interspersed with small crystals of calcareous spar, and often traversed with veins of the same mineral. The backs and cutters of the stone, particularly at Duntocher, are frequently adorned with crystals of iron pyrites, shining with the most beautiful variety of prismatic tints. The stone is of very superior quality, and is extensively used for agricultural and other purposes. It contains from 88 to 94 per cent. of the carbonate of lime.

There is a limestone of a very interesting character, which has been partially wrought for drain and wall stones at Arkleston, near Paisley. It belongs to this portion of the stratification; but its exact position has not been determined. It is a dark coloured ferrugino-calcareous flagstone, abounding with a great variety of impressions of fossil ferns of a peculiar character, terebratulæ chitons, and other marine shells, and some crustaceans. This bed overlies a small seam of good limestone, and a thin bed of coal. Two other limestones occur in this locality, separated from each other by a bed of porphyritic trap. The upper bed is about twenty inches thick. Between it and the whinstone is a stratum of coaly matter, interlaminated with iron pyrites. The limestone below the trap is of a dark blue colour, and is also pyritical. It is about ten feet thick.

On the other side of the great basin, the conditions of this portion of the stratification, although preserving the same general, are (as may be supposed) modified by the local circumstances under which the deposition took place. The main limestone varies from three to nine feet in thickness; but its average is about four and a half feet, and its character is quite the same as at Hurlet, &c. In Carluke and Glassford parishes, the coal which underlies it is reduced to a few inches, though it sometimes attains, at the latter place, a thickness of 2½ feet; both of the limestones, in the Hurlet and Nitshill sections, have their equivalents in the Carluke portion of the basin.

| | | | |
|---|---|---|---|
| 1st, The Kingshaw band, | 2 feet | 10 inches. | |
| 2d, The Foul band (Hosie's) | 3 — | 6 | — |
| 3d, The Main band, | 4 — | 6 | — |

Between the 1st and 2d bands, or posts, as they are sometimes called, there are nine beds of clay ironstone; and there are also two or three lying in shale about the main limestone. This bed contains large orthoceratites, ammonites, Euomphili, producta, and other shells peculiar to the carboniferous limestone formation. The places where it is wrought on the south side of the basin, besides Carluke, are, Nether Auchtergemmel, and Kirkmuirhill, near Lesmahago; Meadowfoot, near Loudonhill; Glassford-mill bridge near Strathaven; Limekilnburn near Hamilton, Rutherend, and Nethanfoot.

The lowest limestone is one which contains in some places a great abundance of organic remains, and is generally characterized by the presence of the producta gigantea, and an abundance of encrinal remains. At Carluke, it is denominated the oyster band. This bed attains great thickness in Ayrshire; but in the county of Lanark it is generally considerably thinner. It is wrought at a place called Hillhead, between Hamilton and Strathaven. It was also once wrought at a place between Paisley and Barrhead; but I am not aware of any other place in Lanarkshire where it reaches the surface in a manner to be accessible. There sometimes occurs a thin layer of coal below it, which, as far as I have observed, may be regarded as the earliest formed coal belonging to this country. Wherever the strata has been seen below this point, there is much disturbance; seemingly to indicate that mechanical transition in the condition of the earth which ushered in the coal era, and gave birth to those important deposits which we have in these papers attempted to describe from personal observation.

## NATURAL PHILOSOPHY AND CHEMISTRY.

### CHAPTER XIV.

#### ON THE PRESENT STATE OF VOLTAIC ELECTRICITY AND ELECTRO-MAGNETISM.

BY Δε Ϻ.

No person, who attentively peruses the various scientific periodicals and treatises of the present day, can fail to be struck by the extraordinary differences of opinion which exist upon points in the different branches of science, generally believed to have been, long ago, satisfactorily and clearly elucidated; but in no branch do we find greater contradictions and perplexities than in the electrical;—for not only do rival theories start up every day—each seducing from the ranks of philosophy a formidable train of partisans—but the very so-called facts of the science, resulting from close investigation, and apparently placed beyond the reach of cavil by the "dicta" of distinguished men, are daily being impugned by the results of researches, conducted upon more accurate principles, and aided by the employment of the various beautiful instruments of modern invention. Thus, what the young philosopher has learned one day, he has to unlearn the next—that is, if he has opportunities of becoming acquainted with all that has been discovered—but, as this cannot be the case with many, the greater number of scientific treasure-seekers spend their lives in pursuing unlucky tracks that have previously led to disappointment, or in delving for wealth which has been already discovered.

Under such circumstances, it is believed, that a sketch of what is at present known concerning Voltaism and Electro-magnetism may not be unacceptable; we therefore propose, in a series of articles, to afford the readers of this Magazine as accurate information as is practicable, upon subjects of such vast importance,—drawing attention as we proceed, to those questions, which, as yet, appear unsettled, and supporting our statements and opinions by the results of experiments conducted by ourselves, with the view of correcting, in some instances, and of enlarging in others, the boundaries of our previous knowledge.

##### Part I.—Of Voltaic Electricity.

1. Electricity is a subtile, imperceptible element,* which is combined with all forms of matter in different and definite proportions; those substances which have the greater proportions being called *plus*, or *positive*, in relation to those which have less—which latter are called *minus*, or *negative*, in relation to the former. "Negative," therefore, in this sense, must not be understood as an expression of opposition to "positive," but rather of comparison.

2. This element may be developed by any action which is capable, directly, or indirectly, of disturbing the natural equilibrium of the atoms of bodies;—therefore friction, percussion, compression, contact, cleavage, heat and light, and even electricity itself, when excited, are each, by a peculiar action, capable of developing electrical effects in all forms of matter without exception.

3. Voltaism may be specially defined to be that peculiar development of electricity, which is produced by a certain arrangement of metals and fluids in contact, and in different electrical conditions.

4. Galvanic electricity, although commonly confounded with Voltaic, is essentially different in its origin—the former arising from the contact of organic bodies, the latter from the contact of inorganic, both classes of bodies being previously in different electrical conditions. The researches of Galvani and his nephew Aldini, unquestionably established the possibility of evolving organic electricity without metallic aid, while to Volta is due the honour of discovering the electric powers of metals, and other inorganic substances; the artificial piles of muscle and brain, first constructed by M. Le Grave, and experimented with by Aldini, present a perfect example of the first, while the original zinc-silver pile of Volta will exemplify the second.

5. It appears, from the recent investigations of eminent philosophers, that electricity, from whatever source it emanates, is one and the same; and that, however different its effects may be, when developed by different means, those effects are produced and governed altogether by the nature of the agents employed in its evolution; that the Franklinian theory of a single fluid, with certain modifications, is sufficient for the explanation of all known electrical phenomena, and, that, therefore, the supposition of the existence of two electricities must be abandoned, not only as unnecessary, but as productive of much obstruction to the progress of the science.

6. In order to generate Voltaic electricity, it is only requisite to divide a box into two cells, by a division of sheet-zinc, and fill one cell with an acidulated, the other with an alkaline, or saline solution; on completing the circuit by a wire made to dip into both liquids, a current will be immediately excited, passing from that side of the zinc in contact with the acid solution, along the connecting-wire, and through the other solution to the opposite surface. This may be considered one of the simplest examples of Electro-Voltaic action between three substances; but, instead of different solutions, the same solution may occupy both cells, provided the mechanical condition of one surface of the zinc be made to differ from that of the other; this may be accomplished by rendering one side rough, and polishing the other side; or it may be equally well effected by making the solution in one cell hotter or weaker than that in the other.

7. But if, as we perceive, one metal and two fluids suffice to form a simple Voltaic circle—conversely, one fluid and two metals will answer the like purpose, and electricity will be developed so long as metallic connexion is preserved between the plates; a repetition of the same substances, in similar order of arrangement, constitutes what is commonly called the Voltaic battery.

8. But, although, as a general rule, metallic communication between different metals, or different parts of the same metal, is a condition necessary for the production of Voltaic effects, it must not be supposed that there is no exception to this rule, and that Voltaic action cannot be produced without it; for, contrary to the opinion of Volta, who held that the electricity of the pile resulted from metallic contact alone, the late observations of Faraday, De la Rive, Schönbein, and others, have proved that electric effects may be developed without metallic contact, provided conducting substances, whose elements being held together by very feeble affinities, are easily disunited, and therefore present but little obstruction to the passage of the current, are interposed between the metals.

9. From this fact, we are enabled to advance a step towards the discovery of the true theory of Voltaic action; for we must conclude, that however necessary metallic communication—as the best medium of conduction—may be for the full development of electric energy, the electricity of the circle can arise without contact; but this does not disprove the observation of Volta, that dissimilar metals are thrown into opposite electric conditions by contact, for the latest researches have shown this to be the case; neither does it prove, as many assume, that the electricity of the pile is caused by chemical action. Faraday's experiment is only useful so far as showing that the contact theory, as announced by Volta and his disciples, is not correct; but it utterly fails as a proof of the correctness of any of the theories that have been substituted.

10. If, then, it be clear that the metallic-contact theory of Volta cannot be sustained, it becomes matter of inquiry how

* Almost all the leading philosophers now entertain the opinion of electricity being material—not a property of matter. The recent discoveries of Moser and Draper, strongly support this opinion. It may be well here to observe, that all our definitions are founded upon the results of the latest researches.

the Voltaic force does originate, and by what means it is renewed? Now, it is evident, that there remain only two other sources which may be supposed adequate to the production of Voltaic action—namely, chemical affinity, and the contact of the fluid and metals. Of these, chemical affinity, or the chemical theory of Wollaston, however variously modified, does not appear sufficient; for inasmuch as we now know that alteration of the electric condition of substances may be produced by fluid-metallic contact, or otherwise, without the occurrence of any chemical change, and that such alteration is sufficient to protect them from chemical combination in some cases, and to promote chemical combination in others, and that such protection or promotion will either prevent or produce Voltaic effects, we may fairly conclude that chemical action cannot be truly considered in the light of a primary cause of the electricity of the pile, but that Voltaic effects are mainly due to certain changes of the natural electrical condition of bodies brought about in the circuit by fluid-metallic contact.

11. Since, however, chemical affinity has been so generally looked upon as a first cause—not only of Voltaism, but also of many other forms of electricity—we are compelled, by our knowledge of the wonderful discoveries that have been made by most distinguished philosophers within the last five years, with respect to the action of light, heat, and electricity itself, in the promotion of (so called) chemical action, before we admit the applicability of any such theory to the explanation of electrical effects, to inquire what chemical action is—whence does it arise—by what means are the existing natural relations of material elements destroyed—new susceptibilities created—new relations established—and new forms and new substances produced?

12. The answer, which the present state of our knowledge enables us to give, is this—that the principle or element called electricity, being inherent in all forms of matter, combining with every substance in definite proportions, and such proportions being essentially requisite for the possession by each substance, of those qualities and attributes which distinguish it from all others and make it what it is; any influence which disturbs the electric equilibrium, or electro-statical condition of the molecules of any body, must so alter and affect the attractive forces by which those molecules are combined, as to dispose the mass to lose its individuality, and assume a totally different form and character.

13. Now, in order to apply those principles to the explanation of chemical and Voltaic phenomena, it becomes necessary to amend the enunciation of those laws which are generally recognised as governing electric action. and also to introduce others. Of the known laws, the three most important are—

1st, Bodies, similarly electrified, repel each other.

2d, Bodies, dissimilarly electrified, attract each other.

3d, The attractive and repulsive forces of electrified bodies vary inversely as the square of the distance. The first two of these laws (which owe their origin to Symmer), do not convey clear or correct ideas of the true action of electric forces; for bodies, dissimilarly electrified, might be taken to mean, charged with different electricities, (which is the meaning of Symmer and Dufay,) no matter whether with similar or dissimilar quantities; and bodies similarly electrified, to mean, charged with electricities of the same kind, no matter whether with similar or dissimilar quantities. These laws, therefore, to be clearly applicable to the theory of a single fluid and electric action generally, should be thus expressed—

Bodies, unequally charged with electricity, attract each other.

Bodies, equally charged with electricity, repel each other.

Bodies, equally charged, repel; and, unequally charged, attract one another inversely as the square of the distance.

14. Such being the more correct enunciation of those important laws, we shall now proceed to inquire how far they apply to, as well as explain, the disturbance of electric equilibrium, and the origin of chemical action in all bodies, which by artificial means are made to contain more than their natural definite proportion of electricity.

15. If we take a strip of platina or copper, and, having divided it into two equal parts, electrify one half, leaving the other in its natural state, and place both in acidulated water, on connecting them, a voltaic circle will thus be formed in which the charged metal will be + to the other, and chemical action will be immediately evidenced by decomposition of the water, and the attraction of its oxygen by the +platinum; but if the + strip be restored to its natural condition, all action ceases, chemical as well as voltaic; for then the two metallic strips are each in a natural electro-statical condition, and there is no cause for the disturbance of the equilibrium; therefore it becomes clear that it is not the metal, *per se*, which exercises any influence in promoting chemical or voltaic action, but the superabundant electricity of one piece of metal, which, acting with great attractive force upon one of the elements of the fluid in contact with that metal, destroys the feebler attractive forces by which their molecules were held together.

16. In the preceding example, we may suppose the + strip of platinum to have been rendered positive, or in other words, polarized by inductive action; but a similar result will obtain, if the platinum strips, instead of forming the primary circle, are made the electrodes of a voltaic arrangement in contact with an electrolyte—that electrode which conveys the electricity of the battery into the interposed fluid, being for the time, in a + condition, in relation to the electrode which conveys the current out of that fluid.

17. In the foregoing experiment, we have an example of electric development in the case of two similar metals (unequally electrified) and one fluid; as well as of the law, that similar bodies, as well as dissimilar, unequally electrified, possess similar attractive properties. But now, if we place a strip of copper in a glass vessel, containing in one portion a solution of sulphate of copper, and in the upper portion, water slightly acidulated—which being lighter, may be made by management to float on the former—we shall find, after the lapse of some hours, crystallized copper deposited upon the part of the metal in the sulphate, and the portion of the metal in the water corroded and oxidized, while the part at the junction of the two fluids retains its original condition. Here the metal employed has not been separated, neither has any portion of it received polarity from the influence of an extra charge, or of electricity passing through it from an external source; and yet, the electric equilibrium has been disturbed, and chemical action has occurred, as is evidenced by the attraction of one part of the metal for oxygen, and of the other part for hydrogen, and the dissolved metal—this state of polarization, and therefore of electric development being necessarily established before attractive influences could operate so as to produce chemical action. Here then we have an instance of voltaic action occurring between two fluids and one metal, and of that metal assuming two opposite electrical states, from contact with dissimilar fluids, which we know to have been in different electrical conditions; and we further find in the experiment a satisfactory and beautiful illustration of the mode of formation of various natural products.

18. But this self-same unaided action of electric forces involves a most important principle; namely, the possibility of throwing bodies into an electro-polar state, by simple contact with bodies less solid, and in different electrical conditions; which bodies, before contact, possessed no more than their natural proportion of electricity in a state of equilibrium. In the former example, we showed how a difference in electro-polarity, and consequently an attractive force, could be produced by overcharging one of the bodies, but in the latter, we have evidenced the production of electro-motive effects without any extra charge, but simply, by the close apposition of heterogeneous substances whose elements were held together by different degrees of force, and the disturbance of the natural electric equilibrium by that apposition.

19. In order to explain the cause of this disturbance of the statical condition of electricity by contact of fluids and solids, we must look for some principle more extended than

that which constitutes the law that held good in our first example,—that law only applying to cases where bodies were charged artificially with more than their natural proportions of the fluid. At the period of the discovery of the laws before stated, voltaic electricity was unknown, and frictional electricity could only be produced by an artificial process which gave an overcharge to one of the two bodies in contact.

20. The principle that we are now in search of is that upon which must depend the production of all chemical action; for, as we have already stated, all chemical action is the effect of a previous disturbance of electric equilibrium, while it may also itself be the cause of further electrical disturbance in other bodies not previously affected;—of course the disturbance of the state of electric equilibrium must involve the disturbance of the equilibrium of the molecules of matter; one disturbance cannot occur without the other, and the double disturbance is chemical action.

21. Contact of heterogeneous substances, or of similar substances, in different electrical states, being therefore necessary for the development of voltaic action, we must infer that when heterogeneous molecules of matter, in dissimilar electric conditions, are sufficiently approximated to be within the range of each other's attraction, then, but not till then, will there be a disturbance of the electric equilibrium of those molecules;—in other words, that element which is — in comparison with that which is + will unite with the latter provided the + state of the latter is superior to the + state of that elementary molecule with which the former has been previously combined. Thus, by this new union, we shall have a new substance formed, which, possessing a larger proportion of electricity than either did separately, or in previous union, will, in its turn, influence any other element or substance (within the circle of attraction,) which shall be negative to it. It is not to be supposed, however, that in all cases, notwithstanding bodies may be brought within the circle of influence, that the + element will enter into union with the — element, because the element with which the latter is associated may not be so positive as the former; it is, on the contrary, requisite that the positive element, or molecule, be sufficiently + to overcome the adhesive force by which the negative *anion* may be bound to its associated *cathion;* therefore electricity may be unequal in bodies, without being sufficiently so to destroy previous combination, in which case, polarization of the molecules will occur, which, although it will weaken the adhesive properties of these molecules, as well as cause a tendency in them to combine anew, will not produce dissolution.

22. Hence we may infer, without much danger of incorrectness in our conclusions—1st, That dissimilar material molecules or elements, naturally but unequally charged, attract each other at insensible distances with forces proportioned to the difference between their positive and negative conditions. 2d, That electricity is evolved as a consequence of the destruction of the original electric equilibrium. 3d, That chemical action is the visible result of the exercise of electrical influences upon bodies at insensible distances; and, we may further infer, that, inasmuch as the adhesive force of elements requires a certain amount of extraneous attractive force to tear them asunder, decomposition and combination will be promoted by any action, which, by removing the elementary molecules farther apart diminishes the attractive force which holds them together. Heat, therefore, is a powerful adjunct in promoting decomposition, and may, in this respect, be considered an antagonistic force to electricity—the one causing the expansion of the mass and consequent separation of the molecules of bodies; the other, their attraction and condensation.

23. The preceding views are such as we are fully justified in entertaining, upon mature consideration and comparison of the results of modern discovery, particularly of those obtained during late years by continental investigators, to which may be added, with all humility, our own. How far they accord with, or approach to, a true theory of the nature and mode of action of electric and molecular forces, it will be for those who are unprejudiced to decide; but whatever may be the opinion respecting the suggested mode of explanation of the peculiar action of those forces, it is quite clear that the theory of a single fluid, which, with certain modifications, we uphold, can no longer be assumed to be at variance with the laws of gravitation. The objection of matter being repulsive to itself is unfounded; for the laws of gravitation, having reference to matter only in its ordinary state, cannot be held to apply in cases of electric excitement. The researches of Mossotti fully justify this assertion. He has adopted the theory of a single fluid, and has shown that gravitation is quite consistent with the assumption of repulsion between the molecules of matter; for if the repulsive force between those molecules be but slightly less powerful than the attraction of electricity for matter, or than the mutual repulsion of the atoms of the electric fluid itself, gravitation must be an immediate consequence of electric equilibrium. This opinion he has supported by strict mathematical investigation, and his results prove that two molecules of matter, accompanied by their electric atmospheres, are mutually attractive when separated by a sensible distance—that the attraction increases on their approach up to a certain point, beyond which the molecules are mutually repulsive;—in this manner, gravitation, cohesion, and the resistance of matter to compression, arise from the same force. We do not say that this theory is the true one, but it certainly approaches truth more nearly than any of the previous ones;—it supports our own views to a certain extent, and proves, beyond all power of contradiction, the utter absurdity of the perplexing, cumbrous, and unnatural theory of two electricities.—*To be continued.*

## CHEMISTRY OF INORGANIC NATURE.

### CHAPTER V.

#### MINERAL CARBON.

Besides the elements of which we have found air, wate and the earths to be composed, there are certain others found in inorganic nature, which remain yet to be examined. The first of these in point of importance, is carbon. This substance in its pure state is far from being plentifully distributed in the mineral kingdom. The only specimen is the diamond, the hardest substance which nature affords. Next in point of purity is graphite, a mineral very well known under the names of plumbago, and black-lead. In this state, carbon exists in considerable abundance, though the fine graphite of Cumberland is still an article of great value for black-lead pencils. In the next stage of purity, however, carbon exists in vast abundance, forming the mineral so well known under the name of anthracite. It is the substance known in some localities by the descriptive names of stone-coal, blind-coal, and glance-coal. The chemical constitution of this coal differs from graphite only in its having in addition to a small and variable portion of iron, which is common to both minerals, a per centage of silica and alumina, which remains as residuum when the coal is burned.

In the United States of America, anthracite exists in such abundance, as to seem absolutely inexhaustible. Pennsylvania alone could perhaps supply Europe with fuel from its stores of it for the next thousand years. In Scotland it is found in smaller patches, but more plentifully in Ireland, where it is known as Kilkenny coal, and in South Wales, where it has of late become of importance as a fuel for the smelting of iron, both by hot and cold blast.

Anthracite differs from common pit-coal in containing no bitumen, and in this we have the reason of its burning without flame and smoke, and also of the difficulty there is in kindling it. Carbon is nevertheless the main constituent of common coal. Coke is this substance in about the same state of purity as it exists in anthracite, and is simply formed by exposing common pit-coal to ignition for some time out of contact of air. In the process, about a fourth of the weight

is dissipated, and the spongy iron-black mass which remains is carbon, more or less pure, according to the quality of the coal from which it was made. It may indeed be reckoned in every respect, except compactness, identical with anthracite—a fact which, although we cannot here stay to insist upon it, goes far in evidence that this last is merely common coal deprived of its volatile matter (bitumen) by subterraneous calcination under pressure.

There is yet another method of obtaining carbon in a state still more nearly pure, and in considerable quantity. This is by the calcination of wood out of contact of air, as in making coke. To obtain the exclusion of the atmosphere, the wood in modern practice is commonly subjected to ignition in close vessels: this allows of the volatile products being retained, and it is with a view to these, that the operation is often more especially conducted. Or the wood may be made up in piles, and covered with loam or the like to screen it from the atmosphere during ignition. This was formerly the general mode, and it is still practised where the carbon is the only product in request. Such carbon is well known under the name of *charcoal*, as a black porous mass without taste or smell. Although very combustible in air, it can bear the highest heat of our furnaces without change, provided air be excluded; it is a bad conductor of heat, but conducts electricity well. When burned in air, it unites with oxygen, and forms carbonic acid—the fixed air of the old chemists, and the choke damp of the miner, the gas which constitutes the sprightliness of champagne, bottled ales, and soda water, and which has so often proved fatal in close apartments heated by charcoal fires.

Charcoal is the basis of the vegetable kingdom, and exists largely in animal structures. But its functions in organic nature are, in the mean time, beyond the province which we have laid out for ourselves. And further, since it is now universally admitted by geologists, that coal is nothing more than the mineralized vegetation of former conditions of our planet, we may dismiss the enormous stores of carbon which we find locked up in our coal-fields, as gifts of organic life, which it would not be strictly correct to enumerate as true mineral conditions of carbon. The examples cited, however, serve to instruct us in the real nature of this important substance, and a few of the many—indeed, numerous—forms which it assumes in the wide range of Nature's economy.

We began by stating, that the diamond is the only pure specimen of carbon which has yet been discovered in a mineral state; and by *carbon*, it will now be understood that we mean nothing more than the pure matter of charcoal. It may, indeed, seem astonishing, that the hardest, most brilliant, and the most valued of all the gems which mineral nature affords, should differ in no chemical condition from a piece of stone-coal—a little impurity in the latter excepted; but it is equally surprising, that this same hard and ponderous coal should be identical in its chemical characters with the soot which may be collected over the flame of a pine torch. This flame, indeed, yields a soot which is almost pure carbon, and which, in this divided state, is well known under the name of lamp-black. This may be collected in almost absolute purity over the flame of a candle, and it is then identical in chemistry with the diamond. This is not a hypothetical assertion, but a fact which has been submitted to the severest experimental scrutiny. We may mention one of the tests of its truth, and it will be enough for our present purpose.

It was stated above, that, when charcoal is ignited in contact with air, it unites with oxygen, and forms the ponderous though invisible gas, called carbonic acid. This is a determinate compound, consisting of 100 parts (by weight) of oxygen, united with 37 parts of carbon. To prove this, suppose that we place a small capsule or cup, containing a known weight of fine charcoal in one or other of its purer forms, under a large bell-glass containing a known quantity of oxygen, and suppose that we ignite the charcoal, by concentrating the sun's rays upon it, by means of a burning-glass; it will, after ignition, continue to burn with great brilliancy, until the whole has disappeared. On examination, the gas in the bell-glass will be found converted into carbonic acid. Every 100 grains of oxygen which it contained will now be found to weigh 137 grains. If more than the requisite quantity of oxygen was present, the portion in excess will be found uncombined and mixed with the acid produced; and, on the other hand, if the charcoal was in excess, a quantity will be found in the capsule after the ignition has ceased. This experiment, varied in every possible way, leads to precisely the same result, and has rendered no conclusion more certain than that this new gas is a compound (in round numbers) of 6 carbon, and 16 oxygen. These elements may, indeed, be again separated. Thus, suppose we ignite a small portion of potassium—the metal which forms the basis of potash—in a known quantity of carbonic acid, it will burn, and at the same time become covered with a black matter, which, on close examination, we discover to be charcoal. The metal, in this case, burns in the gas, because its attraction for the oxygen is more energetic than the attraction of the carbon for that element, and therefore it decomposes the compound gas, combining with the oxygen, and setting the carbon free. Quantative examination informs us further, that for every 6 parts of carbon which we thus recover, 22 parts of the compound gas have disappeared, and that the weight of the potassium—now converted into potash—has been augmented by as much as the difference between 6 and 22. The result of the analysis is, moreover, strictly the same, whether we prepare the carbonic acid experimented upon directly by the combustion of a piece of charcoal, or whether we derive it from a bit of limestone, by the action of some strong acid, or by calcination.

Again, to show that diamond is identical with common charcoal, it is only necessary to ignite a given portion of it either in air or pure oxygen—precisely the same result follows:—every 6 parts of it unite with 16 of oxygen, to form 22 of carbonic acid gas, and the gas so obtained is the same in every respect as that formed by the combustion of a piece of common coke.

By substituting hydrogen gas for the oxygen of the carbonic acid, the compound produced is the gas now so extensively manufactured for artificial illumination—known in chemistry as bicarburetted hydrogen, and popularly by the absurd name of coal-gas. By its combustion, the two products formed are carbonic acid and water, the carbon uniting with one portion of the oxygen of the air and the hydrogen with another. When the combustion is incomplete, a quantity of the carbon is set free in the form of smoke, for which we have of late had so many patent cures.

Having thus satisfied ourselves of the chemical identity of charcoal and diamond—of the blackest and most brilliant productions of the mineral kingdom—we may next ask wherein consists the notorious difference in value? The only answer which we can give to this inquiry is, that the bodies seem to differ only in their states of aggregation: the diamond is charcoal crystallized.

The diamond has not assumed its value in modern times. Pliny mentions it as being the most valuable of human possessions. Besides other marvellous properties which he ascribes to it, he assures us that it is incapable of being heated in the fire, that it cannot be broken until it has been soaked in the blood of a *he-goat*, that it has the double power of destroying the effect of poisons, and of curing insanity, and moreover, that it has a great antipathy to the magnet, which is incapable of attracting iron in the presence of the diamond. It is not necessary to say that Pliny never wrote anything more grossly absurd. So far as he writes history, however, we are willing to believe him trustworthy; and he informs us that "ancient writers describe the diamond as found only in Ethiopia, but that of late it had been brought from India," a part of the world which furnished the exclusive supply of diamonds from Pliny's time till the year 1728, when they began to be imported from Brazil, whence they have been since chiefly obtained.

The ancients valued diamonds on account of their hardness and scarcity: the method of cutting and polishing them was

only discovered about the middle of the last century, at least in Europe, where they were previously worn as ornaments in their native and unpolished state. The inhabitants of India, however, possessed the art of giving this refractory gem an imperfect polish at a much earlier period. Pliny does not mention this, but he informs us that fragments of diamond were valuable for engraving upon other gems.

When the Arabians had conquered Spain, and introduced into Europe the wild fictions and romantic notions of the East, the value of gems increased: a spiritual kind of influence was assigned to them, and they were anxiously sought after as amulets to guard their possessors against witchcraft, evil spirits, poisons, and insanity. In value, the diamond stood in proud pre-eminence over all the other gems, and, although its mysterious properties have disappeared, its nominal value is at this moment as great as it ever was. As an article of real utility, it is only valuable in small fragments —for polishing gems and cutting glass;—but, as an ornament, its value rises with its weight, according to a regular scale—namely, as the squares of the weights. Thus, a rough diamond, of one carat (4 grains), is valued at £2, and one of two carats, at £4 × 2, or £8. A polished diamond, again, is not reckoned to exceed half the weight of the rough diamond from which it was cut; and therefore, as one of a single carat, polished, must have been cut from one of two carats, the price proceeds in regular geometrical progression, from £8 for a polished diamond of one carat, to £3200 for one of 20 carats; but beyond this weight the prices are altogether arbitrary from the small number of purchasers of such expensive toys.

Diamonds have not hitherto been found of large size; but a few have become celebrated on account of their exceeding the average dimensions. Thus, the celebrated Regent Diamond of France, which the Emperor Napoleon caused to be set in the handle of his sword of state, weighs 136 carats, and is now valued at £160,000. It was found in Golconda, and was purchased by Thomas Pitt, grandfather of the great Earl of Chatham, while governor of Madras, for £20,000, and was sold by him to the Regent of France for £100,000.

The Emperor of Russia has a still more famous gem, and which, moreover, has a history. It weighs 193 carats, and is said to have at one time formed one of the eyes of the famous Indian statue of Sheringan, in the temple of Brama, and that a French grenadier, who had deserted into the Malabar service, took such a fancy to it that he became priest to the pagoda. In this capacity he found means to extract the diamond eye, and to replace it by one of glass. His next business was to escape to Madras, where he disposed of the gem for £2000. The purchaser, a ship captain, resold it to a Jew for £12,000. From him it passed, with a decent profit, to a Greek merchant, who finally disposed of it to the Empress Catherine of Russia, for £90,000, and an annuity of £4000. A still larger diamond was possessed in the time of the traveller Tavernier, by the Emperor of Mogul—a kingdom that has since ceased to be;—it weighed 279 carats, (cut) and was reckoned worth upwards of £400,000. But the largest known gem of this order seems to be that belonging to the Rajah of Mattan, in the East Indies. It is of the "purest water," and weighs 367 carats, and therefore, according to the scale, is worth upwards of £1,000,000. It was found about a century ago, and, although its possession has cost several wars, it has remained with the Mattan family for nearly all that time. The Koh-i-noor diamond is well known.

The largest diamond, which has been furnished by Brazil, is in the possession of the crown of Portugal. It weighs 120 carats. Brazil, however, is the only country in the world where diamonds are mined at the present day, and it sends to Europe, annually, from 10 to 16 lbs. of them. Of this quantity about one-third is contraband.

The diamond, as every one knows, is the only substance which is capable of cutting glass. Some other hard substances, it is true, scratch it, but none fairly cut it like the diamond. Dr Wollaston ascribes this peculiar property of the glazier's diamond to the peculiarity of its crystallization in rounded faces and curvilinear edges—the curvilinear edge adjoining the curved faces, entering as a wedge into the furrow opened up by itself, thus tending to separate the parts of the glass For glass-cutting, those rough diamonds are always selected which are sharply crystallized—called technically diamond sparks;—but cut diamonds are never used. In order that the crack, which causes the separation of the vitreous particles, may take place, the diamond must be held almost perpendicularly to the surface of the glass.

The Doctor proved his theory by direct experiment. He caused the edges of a spinel ruby to be cut with the wheel, curvilinear, and the adjacent faces curved, and then found that this stone cut glass as well as the glazier's diamond, though, being much less hard, it did not long retain this property. He repeated the experiment with sapphire and flint, and found that both of these stones acquired the same property.

The depth to which the fissure caused by the glazier's diamond penetrates, does not seem to exceed the two-hundredth part of an inch.

Diamond cutting is effected by abrasion. The diamond to be cut is fixed upon the end of a handle in a small ball of cement. Another diamond is also fixed in a similar way, and the two stones being made to rub against each other with considerable force, mutually abrade each other, and produce those small flat surfaces called facets. Other facets are formed in like manner, by shifting the stones into new positions in their beds, and, when a sufficient number are produced, the stones are fit for polishing. This is done upon a circular plate of cast-iron, charged with the powder produced during the process of cutting. The operations are all upon the principle of "diamond cut diamond."

The structure of the diamond is lamellar, and therefore notwithstanding its great hardness, it is brittle, and gives way readily in the line of its cleavage, affording a direct means of arriving at its primitive form, which is that of the regular octohedron (eight-sided solid.) It possesses either single or double refraction according to its crystalline form; and its refractive power on light is so great in comparison to its density (3·55) that Newton was long ago led to suppose that it consisted of inflammable matter. When it occurs colourless and transparent, it is in general most highly valued as a gem; but rose or pink diamonds sometimes exceed in price even the most limpid. The most common colours are varieties of yellow, sometimes approaching blackish brown. Green is the next most prevailing colour; blue is more rare. Diamonds have been chiefly found in diluvial gravel, and among conglomerate rocks, but its matrix seems to be quartz. It has, however, been generally found associated with a brown iron-ore, and this has led to the belief that that mineral is its original repository. The diamond beds, both in the Indian peninsula and Brazil, consist chiefly of a ferruginous conglomerated sand, enclosing fragments of yellow and bluish quartz, schistose jasper, and grains of gold disseminated with oligist iron-ore—all minerals which differ from those which constitute the neighbouring mountains. The gems are found by washing the debris, and picking them out as they appear. The work in Brazil is carried on by negroes under the strict watch of inspectors; and any one finding a diamond of 17½ carats or upwards, receives his liberty

The diamond, in common with several other minerals, becomes self-luminous by heating, and also by exposure to the sun's light for a certain time. Exposure to the blue rays of the prismatic spectrum augments still more this property of shining in the dark. Besides its great mean refractive power, (index 2·44), diamond possesses a high dispersive agency which enables it to throw out those varied and vivid colours for which it is so highly prized.

Plumbago, as already stated, is not pure carbon; in this the carbon is mineralized in union with a minute portion of iron. This useful substance is not a rare production of the mineral kingdom; it is found in various parts of Europe, and in large quantity in some parts of North America, especially

in New Brunswick. It occurs in gneiss and mica slate, and their subordinate clay slates and limestones, in the form of veins, masses, and kidney-shaped disseminated pieces. The most precious deposit which has yet been discovered, is in the transition slate at Borrodale in Cumberland. The hill is about 2000 feet high, and the entrance to the mine is about 1000 feet from the summit. The mineral was a common subject of robbery about a century ago. "The treasure is now protected by a strong building, consisting of four rooms upon the ground floor; and immediately under one of them is the opening to the mine secured by a strong trap-door, through which alone the workman can enter the interior of the mountain. In this apartment the miners change their ordinary dress as they come in, and after their six hours' post they again change their dress under the superintendence of the steward, before they are allowed to go out. In the innermost room, two men are seated at a large table, sorting and dressing the plumbago; they are locked in while at work, and are watched from an adjoining room by the steward, who is armed with two loaded blunderbusses. Such formidable apparatus is deemed necessary by the proprietors for security." The mineral when sorted, is packed in casks and despatched to London, where it is sold monthly by auction to the black lead pencil manufacturers, at a price varying from 35s. to 45s. a pound. The mine being a pure monopoly, is only worked six weeks annually, and in that time usually yields a produce to the value of from £30,000 to £40,000.

To convert the plumbago into pencils, it is first calcined in close vessels at a bright red heat; then sawn into slender rods which are generally enclosed in cases of cedar wood, though of late years they have come to be used alone in appropriate pencil cases, which are sold under the name of "ever-pointed pencils."

The inferior qualities of pencils are made principally of a compound of plumbago dust and clay, by a process first practised in 1795, by M. Conté, a French gentleman. Both he and M. Humblot, his son-in-law and successor, realized large fortunes by their artificial plumbago.

Although these are the purest forms in which we meet with mineral carbon, and although they do not constitute any considerable part of the earth's crust, yet this substance, in combination with oxygen, is exceedingly abundant. It forms a portion of all those substances which we call carbonates, of which limestone is a notable example. Every 100 lbs. of this substance contains very nearly 12 lbs. of carbon; that is, as much as with water would form about 22 lbs. of sugar. The hardest wood contains only about double the quantity of carbon that limestone does, and potatoes about the same; so that a mountain of that plentiful mineral in any of its forms, contains the essential element of at least an equal bulk of potatoes, and of a forest that would cover many such mountains. Several other minerals exist plentifully as carbonates; the iron ores principally worked in this country are carbonates of iron. Our coal fields are aggregated masses of carbon derived from the vegetable kingdom; from 70 to 99 per cent. of their bulk may be reckoned pure carbon. It is found in our atmosphere in small quantity, but in sufficient abundance to afford vegetable nature its requisite supply. We expire it at every breath, and all our artificial fires and lights while they are fed by it, give it back again undiminished and essentially unaltered, to perform other functions in the economy of nature.

## THE VOLTAIC BATTERY DISSECTED.

### CHAPTER III.

#### ELECTROLYTES.

The Voltaic circles particularly alluded to in the last section, were the zinc-copper, the zinc-silver, and the zinc-platina. In all of these the positive metal is the same; the negative, or conducting metal alone differs. Yet as other metals beside zinc are occasionally employed in place of that metal, it may be well to conclude our remarks upon the metallic arrangements of the battery with a brief description of those combinations in which other positive metals are adopted, and of their respective advantages.

The new Voltaic arrangement of M. Wöhler consists of plate iron as the sole metal, and two liquids, namely, concentrated nitric and diluted sulphuric acids. In this arrangement, the plate of iron which is in contact with the sulphuric acid solution, acts as zinc; the other plate which is uninjured in the concentrated acid, is substituted for the platina, adopted in Grove's batteries. Cast-iron is recommended by Wöhler as preferable to plate iron in such an arrangement; and it is understood that plate iron or cast iron in the liquid described, forms an extremely powerful combination. But as strong objections must ever exist to the use of nitric acid in Voltaic batteries, Wöhler's discovery is only mentioned here, for the purpose of showing the applicability of iron in lieu of zinc as the positive metal.

Iron is occasionally used with diluted sulphuric acid and platinum, the metals being separated by a diaphragm of wood or earthenware, and notwithstanding that one liquid only is employed, the arrangement is found to promote constancy of action. This metal has also been combined by the writer with charcoal, and with wood charred superficially, when substituted for the conducting metal, and with one fluid, and also with two fluids, a diaphragm being interposed. It appears, therefore, from its employment in so many arrangements, that it may be advantageously used, particularly where it is found difficult to procure zinc of the best quality; for there is undoubtedly much less local action on its surface than on that of the zinc generally employed in batteries; and as a generating metal, its powers very nearly equal those of the zinc in similar circumstances. Amalgamated zinc is the best.

In Germany a tin-silver circuit is frequently used, and is found to be powerful, but of course more expensive than a circuit of zinc-copper. Our own experience enables us to recommend iron as next in utility to zinc, and often preferable, as in the case above alluded to; but whatever metal may be used as the positive element of the pile, the precautions and instructions before given with the view of obtaining and preserving the most effective action, will have to be chiefly observed by the experimenter.

*Definition.*—The resolution of a compound body into its elements, or proximate principles, by direct Voltaic action, is termed electrolysis, and those substances which are capable of being so decompounded, are electrolytes.

Liquidity appears to be one essential condition of electrolysis; for the elements of a compound, when held together by very powerful affinities, or by cohesion, cannot be separated except by adequate forces: therefore, as the development of electricity in the Voltaic circle is always accompanied by decomposition, (on which it would appear to depend) any force opposed to separation of the elements of a substance, must also oppose that species of electric action, which is produced by resolution of bodies into their proximate principles.

The weaker, then, the affinities in some cases, but the stronger in most, the more easily will substances be separated by electrolytic action; for much depends upon the degree of conducting power, which is another essential requisite, and to this may most probably be added, a certain atomic relation of the elements to one another.

It is not, however, our business here to enter into a discussion of the laws which are believed to govern electrolysis; there is at present too much difference of opinion upon these points to justify us in making any further allusion to the subject than is necessary for enabling the reader to form some notion of the importance of the liquid element of the battery. Without further remark, we proceed therefore to describe the electrolytes in general use.

Water is essentially an electrolyte—that is, it consists of only two elements combined in the lowest proportions. If those elements were combined in higher proportions, the compound could not be an electrolyte; for no two elements

appear capable of forming more than one electrolyte. Chlorhydric acid and fused metallic proto-chlorides—for instance, the chlorides of lead and silver, and the proto-chloride of tin—are readily decomposed; bi-chloride of tin and other per-chlorides resist decomposition.

But, although an electrolyte, water is by no means an advantageous electrolytic fluid in Voltaic arrangements. The addition, however, of a body or compound, which is incapable of direct electrolysis, increases its conducting power immensely. Now, sulphuric acid, which is composed of one atom of sulphur, and three atoms of oxygen, and is only decomposed by secondary electrolytic action, promotes the decomposition of water, considerably increases electrolysis, and therefore develops improved Voltaic action. Water, therefore, acidulated with sulphuric acid, in the proportion of five parts of the acid to one hundred of water, forms a good conducting and electrolytic fluid. The chief objections to its general employment are, 1st, That it promotes local action where zinc is used; and 2d, That its elements form compounds with the positive metal, which are injurious to the development of sustained currents, by the establishment of counter-currents on the zinc surface.

In the old forms of battery, where but one fluid was used, and no diaphragm, it was customary to add nitric acid to the diluted sulphuric acid; and Faraday recommends for such batteries 4½ nitric, and 4½ sulphuric acid to 100 water. This mixture, however, causes much waste of the generating metal which is not compensated by greatly increased power. It is still, however, employed in some of the modern batteries, but there appears to be a very prevalent opinion that other solutions are far preferable.

Chlorhydrate of ammonia (sal-ammoniac) in solution, appears, by the results of recent experiments, to be decidedly the best conducting and generating fluid for the improved combinations—for where it is employed there is much less local action even with the most impure positive metal; it does not require renewal nearly so often as acidulated water, and the compounds of its elements are not of a nature to counteract the proper action of the combination. It is also much cheaper, in extensive use, than acids, and produces no noxious exhalations. The best proportion of the saturated solution to mix with water will be 25 of the former to 100 of the latter; but where powerful action is desired, the proportion of the chlorhydrate solution may be increased to 50. It may be well to observe, that in purchasing the sal-ammoniac, it will be advisable to select none that is not free from the yellow or orange appearance, often possessed by the commercial qualities, and which always proves the presence of a metallic or other impurity.

On the whole, however, the ingredients which are now generally used are diluted sulphuric acid and zinc—the local action being avoided, by using the latter either in a pure state or amalgamated. Pure zinc is not to the same extent destroyed as the zinc of commerce, but the evil is effectually prevented by amalgamation, for which it is requisite to use milled or rolled zinc, as being the closest in the pores. The process of amalgamation can easily be effected, by placing some mercury in a saucer or plate, and pouring over it a little diluted sulphuric acid; this liquid and the mercury are then brushed over the zinc, previously cleaned also in the acid, till the surface is covered with a bright coat of mercury.

# MATHEMATICS.

## CHAPTER X.

### CONCRETE AND COMPLEX NUMBERS—WEIGHTS AND MEASURES.

The numbers which we have hitherto introduced into our calculations have all been *abstract*—that is, independent of the unit. But these numbers can only give us a clear conception of magnitude and quantity when the unit is defined—that is, when we have determined the value of 1. For example, by the number 24 we specify certainly that the thing to be measured is composed of 24 times the unit; but unless we have a definite idea of the unit itself, it is clearly impossible that we can have any precise conception of 24 such quantities. On the other hand, when we say that a day is composed of 24 *hours*, we then signify that the unit of time of which we speak, is the duration of *one hour*, and that 24 such units are equal in duration to *one day*. Similarly, when we say that a shilling is equal in value to 12 pence, we signify that the unit is one penny, and that twelve of these pence are equivalent to one shilling; and so on with any other examples. Numbers of this sort—that is, numbers composed of a particular unit which is supposed to be known and understood, and which is repeated as often as an abstract number points out—are what we denominate *concrete numbers;* and are, in fact, products, of which the unit assumed is the multiplicand, and the abstract number the multiplier. Thus, 24 *hours* is the same thing as 24 times *one hour*, and 20 *shillings* is the same thing as 20 times *one shilling*. The principle is this—we first of all fix upon the quantity to be taken as the unit, that is, the value to be assigned to one, and then make known how often that unit is repeated.

In making calculations with concrete quantities, no other processes are required than those already explained; but, before proceeding to show the application of the rules established for abstract numbers to calculations of a mixed kind, it will be advantageous to give a summary description of the sorts of units with which it is necessary to deal in the different questions which arise in the ordinary affairs of life.

At first sight it might appear a very simple matter to fix upon the value of the units to be employed in our computations; but a little reflection will satisfy, even those who approach the subject for the first time, that it is attended with great practical difficulty. A uniformity of "weights and measures," has, indeed, been an object of great attention among every civilized people in all ages, but it was only as scientific knowledge became more accurate that approximations were made to the determination of definite standards. Thus, before the introduction of our imperial measures, the system presented no uniformity. The quantity of wheat which was called a bushel in one county, differed from the quantity which bore the same denomination in another. The weight called a *pound* in one locality differed from the pound of another. We had similarly various dimensions of pint and gallon measures, with varieties of ells, acres, *stones*, &c.; and often, the relation which one standard bore to another, was not easily ascertained, and, even after it was found out, the calculations which it was necessary to make, in order to convert the standards of one locality into those of another, were usually long and difficult. Local consumers did not feel the whole disadvantage which arose from this state of confusion; but merchants, who either sent out their own produce to other parts of the country, or imported the manufactures of other localities, often experienced great difficulty in ascertaining the quantities according to their own standard. The same disadvantage and embarrassment are still felt among importers and exporters of commodities—for, as yet, no universal standards have been sanctioned: all that has been attained, is something like uniformity among the people living under the same government, and more particularly in England and France, so that merchants are still under the necessity of comparing the quantities which pass under specific denominations in other countries to ascertain their rates of sale and purchase.

But abiding, in the mean time, by the weights and measures adopted in our own country, in which we are most deeply concerned, it is evidently desirable that these should not only be uniform, but continue the same, and that posterity should be able to replace any one of them when the original measure is lost. Thus our standard of measure of length is the length which we call a *yard*, and a yard, reckoned exact, is kept by the public authorities; but were this destroyed by accident, as was actually the case when the houses of parliament were burned, how are subsequent generations to know what was this length which we call a yard, unless by knowing exactly how it was originally ascertained? And further, to ensure them this knowledge, the measure must be derived from something which cannot be altered by human agency—either by design or accident. Astronomy has furnished the necessary data: the time in which the earth

performs a revolution on its axis, and in which it makes its circuit round the sun, have been determined with great accuracy, and unless some totally unknown change take place in the solar system, we can rely on their remaining the same for a great number of centuries; so that, unless the knowledge of astronomy itself be lost, it will always be known that a year consists of 365·24224 mean solar days, that is very near $365\frac{1}{4}$ times the average interval which elapses between noon and noon.* Now it is found that a pendulum of a certain length—varying, however, with geographical position—makes $31556929\frac{1}{2}$ vibrations during the time that the earth makes one revolution round the sun, and consequently makes 86400 vibrations in the average interval which elapses between noon and noon—that is, in one *mean day*. The time which this pendulum takes to make one vibration, we call a *second;* the time of 60 vibrations we call a *minute;* and the time of 3600 vibrations we call an *hour*. Hence, our denominations of intervals of time according to the following table :—

| | |
|---|---|
| 60 seconds = 1 minute. | 28 days = 1 lunar month. |
| 60 minutes = 1 hour. | 365 days = 1 common year. |
| 24 hours = 1 day. | 366 days = 1 leap year. |

365 days, 5 hours, 48 minutes, 49·536 seconds = 1 solar year.

The calendar months vary in length from 28 to 31 days, according to the well-known rhyme :—

Thirty days have September, April, June, and November,
All the rest have thirty-one, excepting February alone,
Which hath but twenty-eight days clear, and twenty-nine in each leap year.

We have said that the length of the pendulum which vibrates 86,400 times in a mean day, and which thereby divides the day into that number of seconds, and which is therefore called the *seconds' pendulum*, differs in length according to the geographical position of the place where it is suspended; the variation is a minute increase of length as we recede from the equator towards the poles. We must therefore not only know the relation of the length of the seconds' pendulum to our yard measure, but likewise the latitude in which the observations were made. Accordingly, the measure of the pendulum vibrating seconds at the Royal Observatory at Greenwich, has been accurately determined. It would have been very convenient to have called this length a yard, and made it the standard of our measure of length; but before science had stepped in to regulate our measures, there was an entirely arbitrary measure called a yard in use. This had never been very strictly defined; but that which was reckoned the standard was a brass rod which was placed in the Exchequer in the time of Queen Elizabeth, and of which Mr Bailey in his report on the new standard scale of the Astronomical Society, gives it as his opinion that a common kitchen poker filed at the ends in the rudest manner, by the most bungling workman, would make as good a standard. Moreover, he adds, "it has been broken asunder, and the two pieces been dovetailed together, but so badly, that the joint is nearly as loose as that of a pair of tongs; and yet till within the last ten years, (till 1824) to the disgrace of this country, copies of this article were circulated all over Europe and America, with a parchment document accompanying them, certifying that they were true copies of the English standard yard." After several inquiries and reports, the House of Commons at length passed an Act (June, 1824), declaring a yard measure which was made by Mr Bird in 1760, from a scale belonging to the Royal Society, to be the legal standard unit of length; and further, that if at any time the same should be lost, destroyed, or injured, it should be replaced by making another whose length should be to the length of the pendulum vibrating seconds of mean time in the latitude of London, as 36 to 39·1393. As this scale was destroyed in 1834, at the same time with the Houses of Parliament, the country is at present without any legal standard yard, but the relation which it ought to bear to the seconds' pendulum being thus defined, it can at any time be restored.* The unit of length being therefore determined, its divisors and multiples are easily found. Besides being divided into halves and quarters, it is divided into thirds which are called *feet*, and each third is again divided into twelfths which are *inches*. An inch is the smallest lineal measure to which a name is given, but subdivisions of it are made for various purposes: thus on the carpenter's rule, it is usually divided into eighths, and on rules intended for more accurate and scientific purposes, it is divided into tenths, hundredths, &c. Formerly it was made to consist of twelve equal parts called *lines*, and sometimes of *three* equal parts called *barleycorns*,† but these have very properly fallen into disuse. The multiples of the yard are the pole (or perch), the furlong and the mile; $5\frac{1}{2}$ yards make a pole, 40 poles a furlong, and 8 furlongs a mile. The pole and furlong are now very rarely used, distances being expressed in miles and yards. The relations of all these different denominations of lineal measure are exhibited in the following table :—

| Inches. | Feet. | Yards. | Poles. | Furlongs. | Miles. |
|---|---|---|---|---|---|
| 1 | 0·083 | 0·028 | 0·00505 | 0·00012626 | 0·0000157828 |
| 12 | 1 | 0·333 | 0·06060 | 0·00151515 | 0·00018939 |
| 36 | 3 | 1 | 0·1818 | 0·004545 | 0·00056818 |
| 198 | 16·5 | 5·5 | 1 | 0·025 | 0·003125 |
| 7920 | 660 | 220 | 40 | 1 | 0·125 |
| 63360 | 5280 | 1760 | 320 | 8 | 1 |

In the measurement of cloth, linen, &c., the length is expressed in yards, quarters, and nails; the quarter, being the fourth-part of 36 inches, is 9 inches, and the nail is the fourth-part of the quarter of a yard, that is $2\frac{1}{4}$ inches. Depths again are expressed in *fathoms;* and ropes being used in fathoming depths, have often their lengths expressed in fathoms—the fathom is two yards, or six feet. Horses again are said to be so many *hands* high; hand, in this expression, is a name for the third-part of a foot, or 4 inches. In speaking of distances at sea, the term *league* is frequently employed; this is a measure equal to three geographical miles; a geographical mile being the 60th part of a degree, and a degree the 360th part of a great circle of the earth—60 geographical miles are usually reckoned equal to $69\frac{1}{3}$ common miles (of 1760 yards.)

In the measurement of surfaces, the *square yard* is taken as the unit; that is, a square whose side is a yard in length. This unit is subdivided, as in general measure, into square feet and square inches, and its multiples are the square pole, the rood, and the acre. The square foot contains 12 times 12 or 144 square inches; and the square yard, 3 times 3, or 9 square feet. The square pole contains $5\frac{1}{2}$ times $5\frac{1}{2}$, or $30\frac{1}{4}$ square yards; and 40 square poles make a rood, and 4 roods make an acre. Very large surfaces are expressed in square miles.—The following table exhibits, conveniently, the relation of square measure :—

| Square feet. | Sq. yards. | Sq. poles. | Roods. | Acres. |
|---|---|---|---|---|
| 1 | 0·111 | 0·0036731 | 0·000091827 | 0·000022957 |
| 9 | 1 | 0·0330579 | 0·000826448 | 0·000206612 |
| 272·25 | 30·25 | 1 | 0·025 | 0·00625 |
| 10890 | 1210 | 40 | 1 | 0·25 |
| 43560 | 4840 | 160 | 4 | 1 |

* Our year is made to consist of 365 days, and the odd quarter-day is allowed for by adding one day to every fourth year, giving what we call leap year. This is virtually the same as adding a fourth of a day to every year, which is rather too much, since the excess of the year above 365 is not ·25, but only ·24224 of a day: our average year is therefore made too long by ·25 — ·24224 = ·00776 of a day. This quantity amounts to a day in about 128 years, or to a little more than 3 days in 4 centuries. This error is corrected by making only one out of four of the years which close the centuries to be a leap year, Thus, A.D. 1800 was a leap year; 1900 will also be a leap year, but 2000 will not. With these exceptions, we can readily find whether any year is a leap year; for, as this occurs every fourth year, we require only to divide the number of the year by 4; if there be no remainder, it is leap year. Remainders again denote the number of years *after* leap year. Thus, 1851, divided by 4, gives a remainder of 3, showing that it was the third year after leap year, and, consequently, a year preceding a leap year. In the same way, we know that 1852, 1856, 1860, must be made leap years; that is, to each of these years a day must be added, namely, a 29th day must be given to February.

* This will not be so easily done as might at first appear. The seconds' pendulum is one of those constants in nature which it is quite possible to determine within certain limits; very narrow, indeed, but still, perhaps, too wide for absolute accuracy. Besides, the said standard had never been directly compared with the pendulum; and, moreover, the relation of 36 to 39·1393, assigned in the act, is now known to be incorrect, on account of the neglect of certain precautions in the determination of the length of pendulum, which subsequent experiments have shown to be indispensable.

† The inch being originally obtained by putting together three grains of barley.

In measuring land, a chain is used, consisting of 100 links; each link is 7·92 inches, and therefore a surface of 10 square chains, is an acre. This is very nearly equal to a square whose side is $69\frac{4}{7}$ yards. A square mile contains 640 acres.

A cube is a solid of the same length, breadth, and depth, as exemplified in dice. A cubic yard is a cube, each of whose sides measures a yard; it is equal to 27 (that is $3 \times 3 \times 3$) cubes, each of whose sides is a foot, and a cubic foot again is equal to 1728 (that is, $12 \times 12 \times 12$) cubes, each of whose sides is an inch.

For all sorts of liquids, corn, and other dry goods, the standard measure is declared by the act of 1824, to be the *imperial gallon*. The capacity of this standard unit is 277·274 cubic inches; for the act recites that it contains 10 pounds avoirdupois weight of pure water, weighed in air at a temperature of 62° Fah., and with the barometer standing at 30 inches; and that a cubic inch of such water, under the circumstances named, is equal to 252·458 troy grains—7000 such grains being equal to the pound avoirdupois, as will be explained immediately. The parts of the standard unit of capacity are *quarts*, *pints*, and *gills*; 4 gills being a pint, 2 pints a quart, and 4 quarts a gallon. The multiples are the *peck*, *bushel*, and *quarter*: the peck being 2 gallons, the bushel 4 pecks, and the quarter 8 bushels. The denominations of these multiples are only used for dry goods. The following are the relations of the measures of capacity:—

| Gills. | Pints. | Quarts. | Gallons. | Pecks. | Bushels. | Quarters. |
|---|---|---|---|---|---|---|
| 1 | 0·25 | 0·125 | 0·03125 | 0·015625 | 0·00390625 | 0 00048828125 |
| 4 | 1 | 0·5 | 0·125 | 0·0625 | 0·015625 | 0 001953125 |
| 8 | 2 | 1 | 0·25 | 0·125 | 0·03125 | 0·00390625 |
| 32 | 8 | 4 | 1 | 0·5 | 0·125 | 0·015625 |
| 64 | 16 | 8 | 2 | 1 | 0·25 | 0·03125 |
| 256 | 64 | 32 | 8 | 4 | 1 | 0·125 |
| 2048 | 512 | 256 | 64 | 32 | 8 | 1 |

Another imperial measure, used for certain kinds of goods—such as coals, lime, potatoes, and fruits—is *heaped measure*. The gallon is the standard likewise of this measure, and is of the same capacity as the gallon for liquids when filled with water; but the goods are directed by the act to be heaped up in the form of a cone, to a height above the rim of the measure of at least $\frac{3}{4}$ of its depth. The outside diameter of measures used for heaped goods are, moreover, to be at least double the depth. Consequently, they ought to be of the following dimensions:—

| | | | | |
|---|---|---|---|---|
| $\frac{1}{2}$ Gallon | $= 7\frac{3}{4}$ inches diameter | $=$ | 176 | Cubic inches in capacity nearly when heaped. |
| Gallon | $= 9\frac{3}{4}$ do. | $=$ | 352 | |
| Peck | $= 12\frac{1}{4}$ do. | $=$ | 704 | |
| $\frac{1}{2}$ Bushel | $= 15\frac{1}{2}$ do. | $=$ | $1407\frac{3}{4}$ | |
| Bushel | $= 19\frac{1}{2}$ do. | $=$ | $2815\frac{1}{2}$ | |
| 3 Bushels | are called a sack | $=$ | $4\frac{8}{9}$ | Cubic feet nearly when heaped. |
| 12 Sacks | — a chaldron | $=$ | $58\frac{2}{3}$ | |

These are the measures of capacity; we shall next direct our attention to the measures of weight.

It was declared by the Great Charter that the weights should be the same all over England; but perhaps no ordinance was ever so ill observed. Instead of uniformity, the diversity which has prevailed, and which is still very far from being wholly remedied, has been so great as not only to produce confusion and inconvenience, but to render the system of weights adopted in one locality unintelligible in another. From the time of William the Conqueror to that of Henry VII., the old English pound, derived from the weight of grains of wheat, was the standard. This standard was thus derived: 32 grains (of wheat) gathered from the middle of the ear, and well dried, made a pennyweight; 20 pennyweights made an ounce, and 12 ounces a pound, equivalent therefore to 7680 grains. Henry VII. altered this weight, and introduced the *troy* pound instead; this was $\frac{1}{16}$th or $\frac{3}{4}$ths of an ounce heavier than the Saxon pound, and was divided in the same way, except that the pennyweight contained only 24 grains, and consequently a grain troy became much heavier than a grain of wheat; in fact the Saxon pound of 7680 grains was only equivalent to 5400 troy grains, and the troy pound contained 5760 of its own grains. Henry VIII. introduced another weight known as the *avoirdupois*, and though its first object was that of weighing butchers' meat in the market, it came gradually into very general use for all sorts of coarse goods. These two legal measures of weight being thus established, and in common use over the country, the values of their standard units were at length definitely fixed by the Act establishing uniformity of weights and measures in 1824. This act declares the brass weight of 1 pound troy, made in the year 1758, and then in the custody of the Clerk of the House of Commons, to be the standard measure of weight; that that weight be reckoned equal to 5760 grains, and that 7000 such grains be a pound avoirdupois. From this it follows that the pound troy is to the avoirdupois pound as 5760 is to 7000, that is as 144 is to 175. The same act further declares, that should the standard troy pound be lost or destroyed (as has since been the case) that it shall be restored by reference to a cubic inch of distilled water, which in air, at the temperature of 62° Fah., and with the barometer at 30 inches, is declared to be 252·458 troy grains. Hence it follows that the standard troy pennyweight is to a cubic inch of distilled water in such circumstances, as 24 is to 252·458, that is as 24000 is to 252458; so that the cubic inch of water must be conceived to be divided into 252,458 equal parts, and 24,000 of such parts will be the standard pennyweight. In other words, the standard troy pound must be found by determining 22·02346561 .... cubic inches of water. It is needless to say that the restoration of the standard pound in this way is wholly impracticable.

Much has been said respecting the divisions and multiples of the standard units of weight; but we have not space in this article to enter upon the discussion, and will simply content ourselves by stating our opinion that the whole system requires to be radically reformed.

The divisions of the imperial troy pound are still the same as they were when that weight was introduced by King Henry VII. They are as follows:—

| | | | |
|---|---|---|---|
| 24 grains | = 1 pennyweight | (written *dwt.*) | = 24 gr. |
| 20 pennyweights | = 1 ounce | (written *oz.*) | = 480 gr. |
| 12 ounces | = 1 pound | (written *lb.*) | = 5760 gr |

These are the denominations of troy weight when used for weighing gold, silver, and precious stones (except diamonds); but troy weight is also used by apothecaries in compounding medicines, and by them is divided as follows:

| | | |
|---|---|---|
| 20 grains | = 1 scruple | *marked* ℈ |
| 3 scruples | = 1 drachm | . . . ʒ |
| 8 drachms | = 1 ounce | . . . . ℥ |
| 12 ounces | = 1 pound | . . . . ℔ |

For scientific purposes the grain only is used, and sets of weights are constructed in decimal progression, from 10,000 grains down to $\frac{1}{100}$ of a grain. The weight of diamonds is expressed in *carats*;* the carat being equal to 4 grains. When this term, however, is used to express the fineness of gold it has only a relative meaning. Every mass of alloyed gold is supposed to be divided into 24 equal parts, and if 22 of these be pure gold, the mass is said to be 22 carats fine. This is the quality of our gold coin; but what is called the *new standard*, used for watch cases and the like, is only 18 carats fine. The sovereign weighs 5 dwt. and $3\frac{1}{4}$ gr., and contains therefore very nearly 4 dwt. and 17 gr. of pure gold. The shilling weighs 3 dwt. 15 gr., of which 3 parts out of 40 are alloy.

Avoirdupois weight, which is used in almost all commercial transactions, and in the common dealings of life, is exhibited in the following table, in which a comparison of the divisions of the pound is given in troy grains:—

| | | | |
|---|---|---|---|
| | 1 dram | | $= 27\frac{11}{32}$ troy grains. |
| 16 drams | = 1 ounce | | $= 437\frac{1}{2}$ |
| 16 ounces | = 1 pound | | = 7000 |
| 28 pounds | = 1 quarter | *marked* | 1 qr. |
| 4 quarters | = 1 hundredweight | — | 1 cwt. |
| 20 cwts. | = 1 ton | = 2240 lbs. | = 35840 oz. |

* The term *carat*, is said to be the name of a red bean, the fruit of a tree which grows in the district of Shangalla, in Africa, a famous mart of gold dust. The tree is called by the natives *kuara*, a word which signifies sun in the language of the country, because it bears flowers and fruit of a flame colour. Botanists place it in the genus *Erythina*. As the dry seeds of the pod are always of nearly uniform weight, the natives have used them from time immemorial to weigh gold; and, being transported into India at an early period, they have been long employed there for weighing diamonds. Morin, however, derives the word carat from the Arabic word *kyrat*, which signifies a weight, and he thinks that this may again be derived from the Greek word *keration*, a small weight.

The carat of the civilized world is altogether an imaginary weight of 4 nominal grains, a little lighter than 4 grains troy. "It requires $74\frac{1}{16}$ carat grains, to equipoise 288 grains troy."—*Ure.*

These are the statute divisions and multiples of the avoirdupois standard pound; but numerous other discordant denominations, generally multiples of this pound, are still used in different parts of the country for weighing particular kinds of merchandise. One of the most common of these is the *stone*, which has a great variety of different significations. These in London are reduced to two; the stone of 8 lbs. for butchers' meat, and the stone of 14 lbs. for other commodities. In the wool trade we have

| | | cwt. | qr. | lb. |
|---|---|---|---|---|
| 14 lbs. | = 1 stone = | 0 | 0 | 14 |
| 2 stones | = 1 tod = | 0 | 1 | 0 |
| $6\frac{1}{2}$ tods | = 1 wey = | 1 | 2 | 14 |
| 2 weys | = 1 sack = | 3 | 1 | 0 |
| 12 sacks | = 1 last = | 39 | 0 | 0 |

These denominations, however, depend for their value upon the value assigned to the stone, which is not always 14 lb.

It will be observed on comparing the table of avoirdupois weight with that of troy weight, that although the avoirdupois pound exceeds the troy pound in the ratio of 175 to 144, in consequence of the different mode of division, the ounce avoirdupois is *less* than the ounce troy, the former being equal to $437\frac{1}{2}$ grains, while the latter contains 480 grains. It should also be observed, that while the drachm in apothecaries' weight is 60 grains, the dram avoirdupois is equal to only $27\frac{11}{32}$ grains. When these denominations are used, it is therefore necessary to know also the kind of weight; but when grains are spoken of, the denomination is quite well defined; for there are no other grains than troy grains.

For the sake of reference, we may append to this summary a comparative table of the values of our Imperial English, with the French measures at present in use; these last are much more extensively employed in the scientific and commercial literature of Europe than our own; and in books translated from the French into English, the measures are usually given as in the original, and often without any means of making the comparison.

### Measures of Length.

| English Imperial. | | French. | |
|---|---|---|---|
| 1 inch | = $\frac{1}{36}$ yard | = 2·539954 | centimètres. |
| 1 foot | = $\frac{1}{3}$ yard | = 3·0479449 | decimètres. |
| 1 yard imperial | | = 0·91438348 | mètre. |
| Fathom | = 2 yards | = 1·82876696 | mètre. |
| Pole | = $5\frac{1}{2}$ yards | = 5·02910914 | mètres. |
| Furlong | = 220 yards | = 2·01164366 | hectomètres |
| Mile | = 1760 yards | = 1·60931492 | kilomètre. |
| Chain | = 66 feet | = 2·01164366 | decamètres. |
| Link | = 7·92 ins. | = 2·01164366 | decimètres. |

| French. | | English Imperial. |
|---|---|---|
| Millimètre | = $\frac{1}{1000}$ mètre = | 0·03937 inch. |
| Centimètre | = $\frac{1}{100}$ mètre = | 0·39370 inch. |
| Décimètre | = $\frac{1}{10}$ mètre = | 3·93701 inches. |
| Mètre (standard unit)* | = | 39·370091 inches.† 3·280841 feet. 1·093614 yard. |

The multiples of the mètre are the *Decamètre* = 10 mètres, the *Hectomètre* = 100 mètres, the *Kilomètre* = 1000 mètres, and the *Myriamètre* = 10000 mètres.

### Measures of Surface.

| | | | |
|---|---|---|---|
| 1 sq. yard | = 9 sq. feet = | 0·836097 | sq. mètre. |
| — pole | = $30\frac{1}{4}$ sq. yds. = | 0·252919 | centiare. |
| Rood | = 1210 sq. yds. = | 10·116775 | ares. |
| Acre | = 4840 sq. yds. = | 0·404671 | hectares. |

| | | | |
|---|---|---|---|
| Centiare | = 1 sq. mètre = | 1·1959916 | square yards. |
| Are | = 100 — = | 3·9536899 | square poles. |
| Hectare | = 10000 — = | 2·47105699 | acres. |

(The unit of superficial measure is the *are*.)

### Solid Measure.

| | | |
|---|---|---|
| Cubic yard | = 0·764513 | cubic mètre. |
| Stere | = cubic mètre = | 35·31658 cubic feet. |

### Measures of Capacity.

| | | | |
|---|---|---|---|
| 1 pint | = $\frac{1}{8}$ gallon | = 0·567932 | litre. |
| 1 quart. | = $\frac{1}{4}$ gallon | = 1·135864 | litre. |
| Gallon imperial | | = 4·84345794 | litres. |
| Peck | = 2 gallons | = 9·0869159 | litres. |
| Bushel | = 8 gallons | = 3·6347664 | decalitres. |
| Quarter | = 8 bushels | = 2·907813 | hectolitres. |
| Chaldron | = 36 bushels | = 1·308516 | kilolitre. |

| | | | |
|---|---|---|---|
| Centilitre | = $\frac{1}{100}$ litre | = | 0·0704309 gill. |
| Decilitre | = $\frac{1}{10}$ litre | = | 0·7043094 gill. |
| Litre (standard unit) | | = | 1.7607736 pint. 0·2200967 gallon. |
| Decalitre | = 10 litres | = | 2·2009668 gallons. |
| Hectolitre | = 100 litres | = | 22·009668 gallons. |
| Kilolitre | = 1000 litres | = | 3·43901 quarters. |

### Measures of Weight.

| | | | | |
|---|---|---|---|---|
| Troy. | grain | = | 6·477 | centigrammes. |
| | pennyweight | = | 1·55456 | gramme. |
| | ounce | = | 3·10913 | decagrammes. |
| | pound | = | 3·730956 | hectogrammes. |
| Avoirdupois. | dram | = | 1·7712 | grammes. |
| | ounce | = | 2·83384 | decagrammes. |
| | pound | = | 4·534148 | hectogrammes. |
| | hundred-weight | = | 50·78246 | kilogrammes. |
| | Ton | = | 101·5649 | myriagrammes. |

| | Grammes. | | Grains. |
|---|---|---|---|
| Milligramme | = $\frac{1}{1000}$ | = | ·015434 |
| Centigramme | = $\frac{1}{100}$ | = | ·15434 |
| Decigramme | = $\frac{1}{10}$ | = | 1·5434 |
| Gramme | = 1 | = | 15·434 = ·03216 oz. troy |
| Decagramme | = 10 | = | 154·34 |
| Hectogramme | = 100 | = | 1543·4 |
| Kilogramme | = 1000 | = | 15434 = 2·68027 lb. troy; 2·20548 lb. av. |
| Myriagramme | = 10000 | = | 154340 |

The French unit of weight is the *gramme*, which is the weight of the 100dth part of a cubic mètre of distilled water at the temperature of melting ice (32° Fah.)

* This is the fundamental unity of all the weights and measures, and is equal to the 1-*ten millionth* part of the quarter of a meridian of the earth.

† According to Captain Kater, the mètre is 39·37079 inches of the English standard. But Mr. Bailey subsequently determined the length of the mètre to be 39·3696786 inches of the Royal Astronomical Society's scale, and comparing that scale with the imperial yard, he concluded that the true length of the mètre is 39·370091 imperial inches. The comparison is, however, attended with some degree of uncertainty, from the circumstance, that a reduction must be made for the expansion of the metals; the standard temperature of the English measures being 62° Fah., whereas that of the French is 32° Fah.

We shall next month endeavour to show how the rules given in our former chapters for abstract numbers are applied to quantities of the kinds described. This article will then appear to be more useful than it may seem at present. In the mean time, however, the learner should endeavour to familiarize himself with its contents, and he may find in it materials for some very useful exercises in the management of decimal fractions, with which, as well as with common fractions, he is now supposed to be well acquainted. We have indeed something more to say on decimal fractions, but have already gone into the subject quite far enough, until we get a little algebra at our command, which will give us new facilities of investigation.

## HISTORY.

### CHAPTER IX.

#### FIFTH ERA OF ROMAN HISTORY.

This era commences with the admission of all the free Italian citizens to full participation in the privileges enjoyed by the citizens of Rome, and terminates with the subversion of the commonwealth by the appointment of a permanent chief magistrate with sovereign powers. The period is comprehended between the years of the city 665, and 703, when Julius Cæsar assumed the sovereign power under the title of dictator.

During this period there is little growth of the Roman constitution. It is, indeed, too brief to admit of much change that could be worked out by any less energetic means than a revolutionary movement. The materials of its history are, however, very ample; for now we are presented with contemporary annals, and have access to a class of writings which, without being historical, reveal to us more than any history can.

As already indicated, the delegated authority of the state resided in the senate. That body received ambassadors, and resolved, in the first instance, upon questions of peace and war. From the senate an appeal lay to the people; and by the theory of the constitution all new laws, and all amendments upon old laws, after being discussed and reduced to proper form, in the senate, were submitted to the people for their approbation. The senators were the heads of the patrician houses, and men of consular rank; and, latterly, such plebeians were inscribed as had raised themselves to eminence in the state.

There were two kinds of popular assemblies. One of these consisted of *all* members of patrician houses, and the other of plebeians only. The former had, however, fallen into disuse at the period of which we speak, or rather it merged into the meetings of comitia, from which it had never been entirely distinct; there being no distinct line of demarcation separating the newer patrician houses from those of the more powerful plebeians. The meetings of this period were, therefore, composed of all classes of citizens; the plebeian element, however, greatly preponderated. In these meetings magistrates were elected and assigned their offices, and the decrees of the senate respecting war and peace, and the laws propounded by it, were ratified or rejected. The people were thus regarded as the fountain of power; but the senate had a definite and permanent existence, and was, moreover, irresponsible. In the *comitia* every Roman citizen was entitled to take a part; but the constitution of these meetings was shifting and uncertain. They were so from their very nature. Although composed mainly of the permanent residents in Rome, other engagements would prevent many from attending them, and some would stay away from want of interest in the immediate subject of discussion. The adherents of one faction might, from the remissness of their leaders, not receive sufficient warning, while those of another were carefully mustered. Even in regard to the resident population of Rome the constitution of the comitia must thus have been very indeterminate; and this vague and unorganized character was completed by the alternating attendance and non-attendance of citizens resident at a distance. One comitium, therefore, resembled another only in the multitude of individuals composing it; and even this would rarely be the same in two instances. It is, therefore, not surprising that the decisions of these meetings were often incongruous, and that the decrees of one were decried at the next. The decisions of one assembly were, however, as good laws as those of another; for both were the decrees of the sovereign Roman people.

The next predominating characteristic of the decisions of these comitia, was their partisan nature. The citizens at a distance rarely took part in the proceedings, and only in subordinate numbers. But the right of citizenship had been wrested by the provincials from the Romans, because they had found the decisions of the comitia adverse to their interests. The comitia, however, continued to be mainly composed of the old exclusive class; and this class under the irritation of having been obliged to concede the privileges demanded by the Italian provincials uniformly, as opportunities occurred, gave a bias to the decisions of the comitia to the disadvantage of the non-resident citizens. Besides, the most constant attendants in the comitia were the idle, improvident and reckless of the metropolis—individuals who not unfrequently sold their own interests into the hands of a wealthy and ambitious few who turned their influence to account in the promotion of their own selfish ends. There was the mass, however, ready to chime in when the proper chord was struck—when their interests or their passions instigated them to activity. To oppress the provincials and annoy the senators, were the most popular objects of their exertions. In this last, although they seized upon every opportunity to gall the pride of their haughty lords—as a crowd they possessed neither virtue nor intelligence enough to devise and pursue a systematic and effectual course of opposition. The stern honesty which many brought with them to the comitium was neutralized by the venality of a demoralized mass in their own ranks, and by the hood-winked and ignorant tools of patrician-paid demagogues. Hence, while the deliberations of the senate were sagacious, consistent, and calculated to promote a rational policy—biassed, it is true, by arrogance and selfishness—the deliberations of the comitia were passionate, fickle, narrow-minded, and only redeemed at times by glimpses of generous emotion and true intelligence.

Under all circumstances the functions of a state must be delegated to officers. These functions are judicial, executive, and military. In Rome the military department alone was adequately organized. But, in addition to evils arising from inadequate organization, the different functions were not sufficiently separated—the same officer discharged the judicial, executive, and military duties. These duties were often very incompatible, and their accumulation in the hands of one officer productive of much serious mischief.

The judicial functions were discharged sometimes by the senate, at other times by the comitia, and again by the consuls and proconsuls; but more permanently by the prætors, quæstors, ediles, tribunes, by the arbiters appointed from among the senators, and the *judices* appointed from among the plebeians.

The law according to which these tribunals framed their decisions, sprang from tho relations of society in Rome. The doctrine respecting property was well developed and sharply defined. Only freemen were capable of holding property, and only Roman citizens could possess land-rights. The doctrine regarding the status of individuals, the distinction between freemen and slaves, between citizens and non-citizens, men of mature years, females, and pupils, were also fully and accurately laid down. Even the notion of the personality of a corporation was perfectly familiar to the Romans; and the law relative to marriage, to which attention had been directed at an early period by the non-recognition on the part of the patricians of intermarriages of plebeians into their families—and the difficulty to be apprehended should slaves be permitted to contract so enduring a tie, was clearly defined in all its details, and regarded as a branch of the law respecting personal status. The legal doctrine of obligations was even better defined. The fierce struggles between the patricians and plebeians, during the infancy of the republic, occasioned mainly by the cruel extortions of the wealthy class when creditors, had caused this portion of the law to be laid down with the utmost precision.

These were the three great heads to which the attention of the Roman lawyers was directed; they included the whole code of distributive law. There was, however, no such thing as systematic legislation at Rome. The lawyer was left to supply *hiatus* which he found in the written law by following out the analogy of what he found in the code, and by quoting in support of his opinion some previous decision. On rare occasions, when popular

discontent had forced the authorities to action, or when the interests of some influential individual was concerned, special pieces of supplemental legislation were resorted to.

A law, properly so called, was a decree, introduced and propounded in the senate, and sanctioned in a *comitium;* but when the patrician power predominated, the force of law resided in a mere *senatûs-consultum*—a resolution of the senate—and this force it retained by prescription after the temporary ascendancy had passed away. On the other hand, when the popular party held sway, the force of law was a decree of the popular assembly; and this, like the other, retained validity by prescription. Owing to these contending sources, the Roman distributive law, although systematic and coherent in itself, existed nowhere as a whole except in the minds of the lawyers. It was a sealed book to the mass, and thus a license was given to individual judges to wrest it with impunity in individual cases.

The penal law was in a still lower state. The Roman citizen could be proceeded against only in flagrant cases, and was then liable to very inadequate punishment. On the other hand, non-citizens were left very much at the mercy of an arbitrary judge. Slaves again were not recognised as persons by the tribunals; they were mere vessels of clay to be broken or preserved according to the whim of their private masters. It is not, therefore, surprising that the provisions of the Roman penal law were few; they were generally enacted in moments of intense political excitement, and with reference to a special case.

The great defect of the Roman law was its indefinite character arising from its being nowhere written down, and therefore liable to be modified by individual opinion in particular cases. It was, moreover, unknown to the great mass of the citizens—long study being requisite to extract a knowledge of its details on account of the multiplex and often obscure and contradictory sources whence they had to be derived. Another defect was the imperfect organization of the courts in which it was dispensed. In Rome there was a superabundance of courts, but their jurisdiction was very imperfectly defined. Public cases went, of course, before the supreme magistrate; but, in private cases, the defendant knew not before what judge he might be dragged. One judge was overwhelmed with business while another had nothing to do. There was, besides, no subordination of courts with a view to facilitate redress by appeal. In the provinces it was still worse. There certain cases only were competent in the court of the governor, while in all the inferior courts, an appeal lay to the governor's court. The governor was military commander, head of the executive of the province, and judge. Independently of his owing his appointment to the venal elections of Rome, he might be, and frequently was, totally ignorant even of Roman law and consequently of those provincial laws which had been allowed by treaty to remain in force; and, further, the immense business flowing in from an extensive district of country—districts which have since been subdivided into kingdoms—was more than any one man could efficiently overtake. Imperfect management, and inevitable injustice, were the consequence. Wealth and influence usurped the functions of law, and at their hands the poor man had no redress. The rich man, when sued by an opponent less wealthy, had only to appeal from the inferior to the governor's court, and thence to Rome, where he could protract the suit indefinitely.

Within the boundaries of the Roman state the law was known only to those who had wealth and leisure for protracted study, and talent of the highest order. Whoever wished to obtain justice was necessitated to put himself under the protection of one of this class, and become his *client.* This law-dispensing class were not, however, content with the money-fees of their clients—these unfortunates were forced to buy their services at a dearer price, by becoming their courtiers, their dependents, their political retainers, and partisans. The study of law thus became the surest way to political eminence—the eminent lawyer could aspire to the highest offices of the state. He availed himself of his legal skill in two ways—to acquire the admiration and confidence of the multitude, and to attach to his interests a trusty band of agents engaged by every consideration to promote his ambitious ends.

The distributive law of Rome still survives as a noble monument of human genius; but in the state which gave it birth, it was a goddess imprisoned, and in whose name the utmost iniquities were perpetrated by the custodiers. *Law* was a spell-word, whose meaning was only known to a few, and who turned their knowledge to use solely for their own selfish purposes and individual aggrandizement.

The executive organization of the state was still more defective. The provinces were farmed out, and the mode of managing the national finance was most oppressive to the tax-payers, little productive to the state treasury, and most destructive of public morals. It was in the provinces alone that taxes were paid—the citizens of Rome having been exempted from taxation by the conquest of Macedonia. It was at Rome that the taxgatherers were appointed, and at Rome only complaints could be brought against them. It was the interest of the resident Roman citizen that the highest possible rent should be obtained from the provincial tax-farmer, and it was the interest of the latter to extort as much as possible from the tax-paying population, over and above what he paid into the state treasury. The wealthiest competitor for the farming of the revenue of a province was the most likely of success: he had the means of making himself popular among the venal electors; and once popular with them, he was certain of the patronage of the ambitious intriguers for the higher offices of the state.

That branch of the executive intended to enforce judicial decrees, prevent crime, and repress popular outbreaks, was extremely ill-provided for. In tranquil times, public opinion deterred men from refusing to obey their citations; but in times of popular excitement, the despatches of the magistrate were little respected. In the provinces beyond the limits of Italy, there were standing armies which supplied the place of a police; but it was only on extraordinary occasions that they were called in, chiefly indeed when the dignity of the Roman state was concerned. They were inavailable for daily use, and the officers of the executive had no other efficient force at their disposal. Their lictors were more for show than use. Even their functions, and the forms according to which they were to proceed in the discharge of their duties, were not prescribed by any definite constitutional law. The limits of their authority being thus unsettled, they were necessarily feeble in the discharge of the all-important daily duties of police; and were arbitrary and unrestrained when circumstances armed them with a temporary power.

Of all the Roman institutions, the army alone was well and adequately organized. Circumstances had made the Romans from the beginning a nation of warriors, and as their resources increased, their skill in using them increased also. From the time that the Trans-Italian provinces were regarded as permanent dependencies of the state, standing armies were indispensable. Civilized nations possessing a history of which they were proud, paid a reluctant obedience to a foreign power, whose civilization was comparatively young. Uncivilized tribes, with the fickleness of barbarians, threw themselves at the feet of the Roman power one day, and rose in arms against it on the next. To keep their new subjects obedient, it was necessary to have armies permanently stationed among them; such warlike provision was requisite to keep down the turbulent spirit of nations naturally as fond of war and conquest as the Romans themselves. Those armies were standing schools of military science, and although the commanding officers were appointed by the constituency of Rome, necessity made them in general very judicious. It was for the interest of all Romans that the best generals should be appointed; and their officers had a sufficient motive to exertion in the knowledge that their command would remain in their hands no longer than they continued successful. The constitution of these armies was, however, essentially different from that of the armies of early Rome. The citizens, in easy circumstances, and averse to the unremitting toils of the soldier's life, had relinquished service in the ranks to needy adventurers. The ties which bound such men to their homes were slight enough at first, and in the course of a protracted service were entirely obliterated. The camp became their home, and the standard the object of their practical worship. This is true of the legionary soldier—the Roman citizen; and it was still more emphatically true of the auxiliary complements, composed of non-citizens, who felt that while they continued soldiers, they possessed privileges and an importance which did not belong to them in private life. The commander was, moreover, the supreme judge, and the head of the executive of his province. He exercised a power within it, to which the precariously exercised supremacy of Rome opposed few checks. So long indeed as he possessed the affection of the soldiery, he had little to fear: he

could, in case of opposition, impose his own terms upon the faction which for the time was in the ascendant at home.

In this sketch of the civil institutions of Rome, it remains to notice the character of its religious hierarchy at this period. Here, however, we meet with little change. The popular creed remained in the main what we have already described it. An immense number of new gods had, indeed, been introduced to Rome, and grafted upon the old mythology. But these deities did not gain admission to the pantheon, through the mere whim of the Roman populace: their reception was dictated by a sound policy, to which the Roman arms owed much of their success. This policy developed itself at the commencement of their career; for they soon learned that spiritual arms were as effective as physical force in subduing the hostile tribes which surrounded them. When they laid siege to a city, they did not at the same time neglect to do honour to its tutelar deities, to win them over to their favour, promising them finer temples and richer sacrifices in Rome, should they desert their old worshippers. This had usually its effect with the priests, if not with the deities, and, in consequence, with the people, who, feeling themselves deserted by their gods, yielded more readily to the Roman arms. The new deities were installed at Rome accordingly. It was this same policy, grounded upon the natural superstition of ignorance, that caused the name of the tutelar deity of Rome to be kept a profound secret, lest armies should retaliate. This chief deity was a being without a name; it was even unknown whether it were a god or a goddess. The performance of the rites of public worship were assigned to the pontiffs and augurs; the latter inquired into the future, and the former performed the prescribed lustrations and sacrifices. At first both offices belonged to the patricians; but latterly the plebeians acquired a right to vote in their election, and finally a right to appoint one of their own number to the augural college. The knowledge of the mysteries still, however, continued with the wealthy and powerful; and by these they were looked upon simply as a convenient means of restraining the ignorant and superstitious populace: the Roman religion had in fact become a state engine, and was only regarded as such by the upper classes.

We have been repeatedly led to remark, that the distinction between patricians and plebeians had by this time become nearly obsolete. The poor patrician houses had lost their influence, and subsided into private life. Some again of the most powerful houses of Rome were of the plebeian caste. One by one all offices of the state, and next the offices of religion, had become accessible to plebeians. But in order to obtain them—the election being in the hands of a corrupt populace, a preliminary career was necessary, a career which implied the possession of considerable wealth either by the individual or by his relations. The range of parties eligible to office was as narrow as before; but it was no longer birth, it was wealth that marked out the limits. The great patrician houses, the descendants of tax-gatherers and successful soldiers, composed the fortunate few. The names of patrician and plebeian however outlived their original significations, and became the watchwords of political factions which, under the plea of patriotism, contended with each other for the possession of state offices and dignities which they made use of for their own special aggrandizement.

The tone of society, meanwhile, differed in different parts of the state. In Italy, the predominating tone was rustic. In Gaul and Spain, it was that of barbarians aping the superior refinement of their conquerors. In Greece, it was polished. In Numidia, it was barbarism, with an occasional and partial gleam of the civilization introduced by the Carthaginians. In Asia and Egypt, it was voluptuousness tempered at times by Grecian refinement.

The power-holding class throughout the state retained much of the old Roman energy. The necessity of struggling for ascendancy in the camp, in the courts of justice, and in the popular assemblies, afforded them both mental and physical exercise, and formed the character; and the extent of business in which they were habitually engaged, gave them dignity of deportment. A few of them had contracted a taste for Grecian literature and philosophy; and many pursued the same studies because they saw the advantages which others derived from them. Still, the great proportion even of this class were illiterate men. This is forcibly confirmed by the fact, that even later than the birth of Cicero, they enacted a law forbidding the prosecution of literary studies.

The rural districts of Italy had been by this period drained by the wars of the republic of the best portion of their free population, and the patricians had possessed themselves of the greater portion of the soil, which they cultivated by slaves. The tax-gatherers in emulation of the old patricians, in like manner made themselves possessors of large tracts of land, which they cultivated by the same means. In this way, the depopulation of the country may be said to have been completed; it had a population of lords and slaves, but a free labouring population was nowhere to be found. It is indeed to this period that we are to refer the depopulation of Italy, so often and so erroneously attributed to the devastations of the northern tribes at a later period. At the period of which we speak, the villa of a wealthy Roman citizen usually occupied the site of a city, which had its name in the annals of ancient Rome. The territory for miles around was cultivated by his slaves. The little free population that remained was poor and ignorant; and being despised by the wealthy, it learned to despise itself, and associating only with slaves, it gradually sank to their level, and blended with them.

In the dependent Trans-Italian states, the name of citizen had a signification. It conveyed no real power; but it promoted the interests of such as chose to become the parasites of a governor. It was a title of rank constituting the bearers the minor nobility of a minor court. The free class of non-citizens, if they were poor, were little superior to slaves; if rich, they had no career of ambition open to them. Their only occupation was to intrigue against the overwhelming power of Rome, and to settle feuds among themselves.

It might seem at first sight that, in the unhappy condition of slaves, there could scarcely be sufficient variety to render detail necessary. The epithet *slave*, however, attached to widely different conditions. The wars upon which the Roman power had grown so gigantic, had caused the slave population infinitely to out-number the free. In some of the eastern regions, the power was in the hands of the slaves; and in many of the nomadic tribes of Arabia, and among some of the less advanced Celtic tribes, and even Libyans, the difference between bondsmen and freemen was little felt and easily effaced. It was in central Rome and the adjoining provinces, that the chain of slavery weighed most heavily. Yet even there, there were exceptions. By the chances of war, many highly educated individuals, brought to Rome as slaves, acquired sufficient influence by their talents greatly to alleviate their lot, even when they did not obtain enfranchisement. The earliest *literati* of Rome were slaves of this class; and the pedagogues by whom the children of the wealthy Romans were instructed, were slaves. The confidential secretary, and the master of the household were usually of the same class. But the domestic drudges, and those of lower qualifications, drank of the draught of bondage in all its unqualified bitterness. Nor was even their lot the worst, holding, as they did, life itself at the mercy of a private despot. Many wealthy Romans kept troops of gladiators composed of slaves, whose business it was to butcher one another for the amusement of their lordly Roman masters.

We formerly mentioned the Illyrians as a piratical nation; but piracy was not confined to them. Every maritime state that was dismembered and erected into a Roman province, sent forth its bands of pirates, and every inland state similarly circumstanced, produced bands of robbers. These were at first the hardy soldiers who disdained to wear a foreign yoke, but were speedily augmented in numbers by desperadoes whose business it was to prey upon all parties. Runaway slaves, fugitives from justice, deserters and disbanded soldiers swelled their ranks, and gave them importance. These gave the Romans much trouble; and the swarms of pirates on the coast of Illyria and Epira, around Crete, in the harbours of Thrace, Asia Minor, and the Euxine, occupied their attention for more than a century.

Having thus passed in review the various classes which constituted the society of the Roman state down to the period now under notice, we are enabled to reconcile the seeming inconsistency and incoherency of its history. We see how it was that the state which was sufficiently powerful to crush monarchs, was incompetent to extirpate bands of robbers. We see how the city which vanquished the colossal power of Carthage, set in motion by the genius of Hannibal, trembled before Spartacus at the head of a few gladiator and fugitive slaves. Above all, we can understand how Cicero and Cataline could be citizens of the same city at the same time. We see the genius of the one developing itself in the schools of Greece and expanding under

the applause of the better spirits of his age. We see the latter amid the license of the camp, exposed to the contaminations of associates who had grafted upon the rusticity of the Roman character, the sensual voluptuousness of the Asiatic Greek, and the reckless avarice of the soldier's life. We can see how in such a nursery, there might grow up the prodigy of sensuality, avarice and tyranny, which history presents to us under the name of Cataline.

The history of Rome, during this period, is wild and discordant. The unsettled institutions and imperfect organization of the state allowed free scope to the exercise of the wildest passions. The upholding of religion by men who had emancipated themselves from its belief, and the want of a moral element in the popular creed, substituted conjuring for religion. The scanty precepts of household morality were thrown aside, before men had attained to the knowledge of more comprehensive ethics. Wars without, and civil broils within, generated a spirit which, trampling upon all the finer sentiments, became coarse as it waxed strong in daring. The management of the public business was ostentatious, but in all that regarded personal security, the state was a chaos. The triumphal procession was succeeded by the flow of civil blood in the forum; the stately pageant of sacrifice to the gods, and the procession of white-robed priests, was followed by the barbarous spectacle of gladiators. For a moment we stay to admire the wisdom imbodied in the code of distributive law bequeathed by men of that age as an invaluable legacy to the civilian; and we listen with delight to the philosophic discourse of Atticus and Cicero, but our attention is immediately drawn off to Cataline amid his conspirators quaffing the sacrament of blood.

The influential events which characterize this period succeed in rapid succession. The forms of the constitution are preserved only to be perverted to serve the purposes of the powerful. Whoever had wealth, adherents, and energy, might command the state. Marius was its virtual sovereign at the beginning of this era; Sylla succeeded Marius, and Pompey succeeded Sylla. But Marius, Sylla, and Pompey, all exercised their power ostensibly according to the forms of the commonwealth. Others who attempted to grasp at their power in defiance of these forms, failed: the virtue of habit was still too strong in the mass to submit to open despotism. The incessant shifting of power from one blood-stained hand to another, was, however, rapidly breaking down this last remnant of independence. It had long since ceased to be a rational conviction; the power of the Roman state had outgrown its intelligence; complex relations crowded themselves upon men faster than they could make legal provision for them; perplexing political problems sprung up, demanding, like the riddle of the sphinx, instant solution under penalty of death—the burden outgrew the strength of the bearer. This state of things produced bewilderment rather than energy. Men became terrified and eager to purchase counsel from any quarter at any price. The tyrannies of Marius and Sylla had been comparatively innocuous. This was remembered amid the endless and aimless broils of the republic, and as it was remembered, it had its influence in disposing men rather to hazard political slavery, than submit longer to the rank and growing anarchy which polluted the moral atmosphere of Rome. Cæsar stepped in at this moment, and his was the genius to restore order.

Cæsar's assumption of supreme power has been called usurpation; but this is incorrect. Cæsar took the reins of government with the approbation of a majority—an overwhelming majority—of the people he was to govern; and that his government had the concurrence of an overwhelming majority of the same people is proved by the single fact, that it required a conspiracy and an assassination to remove him from his seat;—an appeal to the public was out of the question. Even after he was removed, the knot, unloosened by the assassins, was immediately re-knit by the very inferior Octavius. The fulness of time was come, and Cæsar's was the genius created for the occasion. In this we have the explanation of his elevation to the supreme power in which perished the crumbling constitution of republican Rome.

Having now brought down our history to that point at which the nominal republic is rapidly merging into an empire, we shall proceed to review the separate parts of which this mighty empire was composed, and in next chapter we shall give some account of the Persian and Egyptian dynasties, up to the period of their absorption within the "imperial Zollverein" of all-conquering Rome.

# AGRICULTURE.

## CHAPTER I.

### INTRODUCTORY.

Agriculture, or farming, is the name given to the art, by following the rules of which we are enabled to rear and fatten domesticated animals for food or other purposes, and to raise crops of those vegetables that are necessary for our sustenance, employed for making clothing fabric, or used in the arts. These vegetables must be necessaries; and when those are cultivated that are consumed as luxuries, we give the name of horticulture, or gardening, to the process. Further, it is essential to the idea of agriculture, that the operations be conducted on a tolerably extended scale; and we do not apply the word to crofters' allotments and the like: such, we say, are managed by the spade husbandry.

Several different kinds of farming exist in Great Britain. One kind is practised in the neighbourhood of large towns, and consists in selling the whole of the produce, including the hay, green crops, and straw, to the occupants of the town. No stock is kept, but the necessary supply of manure is purchased in the town. A farmer of this kind requires to thoroughly understand the cultivation of arable lands, and particularly of green crops, such as turnips and potatoes, as these produce, in such localities, the most return per acre. A knowledge of stock is, however, not necessary. Farms in the vicinity of large towns let at a very high rent.

Another kind of farming is carried on in what in Scotland is termed a *carse*. A carse is a tract of land consisting of very deep soil of alluvial and diluvial clay. Such land is particularly suitable for raising grain crops, but not well suited for grasses, and therefore not calculated for raising stock. A number of cattle are bought in winter for the purpose of eating the turnips and straw, so as to afford manure, but no sheep are kept. A carse farmer, in order to succeed, must thoroughly understand the raising of grain crops, as in carse districts, not in the immediate neighbourhood of large towns, these crops yield the greatest return per acre.

Another kind of farming is dairy farming. In it the main object is the production of butter and cheese; and a dairy farmer must understand well the selecting, breeding, and management of milch cows, and the manufacture of their productions. Usually, too, a considerable number of pigs are reared and fattened upon these farms. But little attention is paid to either fattening cattle, or the management of arable land. Many dairy farmers add to the above employment the breeding and rearing of horses. Generally speaking, dairy farms let at lower than either of the above-mentioned kinds.

Another kind of farming is confined to the breeding and rearing of cattle and sheep, and only practised in pastoral districts, such as Wales, the Western Highlands and Islands of Scotland, the Cheviot Mountains, &c. Sometimes both cattle and sheep are reared upon the same farm, in which case the cattle are principally confined to the lower-lying part of the ground; but the more general plan, perhaps, is for a farmer to confine himself mainly to one kind of stock. There is no cultivation of arable land, save a little for corn and potatoes for the use of the farmer, his servants, and horses, and a few turnips for the use of the stock in winter. But natural hay is the principal source of food to the animals at that period of the year. A pastoral farmer requires to thoroughly understand the breeding and management of live stock. Land, in pastoral districts, usually lets at a very low rate per acre.

There is a fifth kind of farming, called the mixed husbandry, which combines all the above, and consists in rearing cattle, sheep, horses, and pigs, and consequently in cultivating artificial grasses, in growing root and grain crops, and in keeping milch cows. It is practised upon arable land not in the immediate vicinity of large towns, is the least uncertain (inasmuch as corn, root crops, and stock cannot *all* go wrong in one year), and by far the most agreeable of any. In the present treatise, in giving directions for farm management,

we suppose the existence of such a mixed husbandry farm, and then endeavour to obtain completeness. Farms of this kind vary a good deal in extent; but one of about 250 acres will afford a livelihood, without requiring an excessive amount of capital.

It is essential to success in farming to have a well-trained and instructed staff of servants. It is to the superior intelligence of the farm servants of the Scottish lowlands and the north of England, that by far the greater part of the more productive farming there existing is to be ascribed. We proceed to describe the various ranks and duties of farm servants as they are in those districts.

Highest in rank is the steward, bailiff, or grieve. He is to the farmer what a first-lieutenant is to the captain of a ship. The farmer communicates to him his plans; states generally what he wishes to be done, and leaves to him the practical carrying-out of the necessary details. He has full control over the ploughmen and cattlemen and field-workers; but, unless expressly arranged, his authority does not reach the shepherd and hedger. He keeps the keys of the granaries; delivers out the corn for the horses, and other food for the animals; instructs the ploughmen and field-workers every morning as to the work they have to do, and personally superintends its execution. Personally he does not labour at any ordinary toil; but many tasks of the farm fall to his hands. Thus, he sows the seed-corn; builds the stacks; feeds the thrashing-mill; and winnows the corn. A grieve always gets the best servant's house, and this, with a garden, is invariably free. His wages are paid either in money only, or, as is usually the case, partly in money and partly in kind. A common plan is to give him a cow's grass and straw (he providing his own cow); sixty-five stones (14lb.) of oatmeal; four bolls (of 8 bushels) of potatoes; the carriage of his coals and his food for thirty days of harvest; and about £15 in money. There is not a more intelligent, respectable, and comfortable class of men than the farm grieves.

The cattleman is an important functionary upon the farm. He is very often a steady old ploughman, who begins to find a ploughman's labour a little too heavy for him. A cattleman has no hard labour to perform. It is his duty to clean out the byres and cattle-sheds; to supply fresh litter; and to furnish the animals with the kind and amount of food that the steward has ordered. He also, when cattle are currycombed and brushed, does these. When the cattle are pastured, he takes care that there is a due supply of water, and he brings the cows to the appointed place to be milked. He observes when the cows are in season, and keeps a record of the time when they were served with the bull. In harvest-time, he generally helps to prepare, and carries to the field, the reaper's food. In summer, he performs odd jobs; and often he is the person fixed upon to groom the farmer's riding-horse. His wages are not more than those of the ploughman, immediately to be stated, and sometimes less.

The shepherd considers himself equal to the steward. He has the sole management of the sheep. He is expected to visit his flock at the early morning and again at evening, and, during the day, to be moving about pretty much among them. In winter, he has to feed his young and fattening sheep upon turnips, and upon what else the farmer has fixed upon. In spring, he has to watch the ewes about to lamb, almost day and night. He also superintends and assists in washing, clipping, and smearing the sheep. He has, too, to wean the lambs, castrate them, draft out the aged sheep, and carefully watch for the first intimations of disease. On small farms, he makes nets, and often takes charge of the riding-horse. Besides the wages of a ploughman, a shepherd is allowed to keep a flock of ten Leicester ewes, two of which he sells every year, he being entitled to retain as many ewe-lambs of his flock as will keep up his number. In the purely pastoral districts, he is allowed a house and garden, potatoes, six bolls of oatmeal, and forty-five blackfaced sheep.

A hedger is another upper farm-servant. He is sometimes called a spadehind. His duty consists in taking charge of the hedges, ditches, and drains of a farm. He cuts the old hedges, plants new ones, cuts and keeps clean ditches, and cuts surface drains across the ridges to facilitate the escape of superficial water. Besides these, a hedger, who has usually been a ploughman, and promoted for steadiness and skill, can usually, if required, perform the nicer operations of the farm. He usually receives his wages in money, and gets (besides his house and garden) from £40 to £50 a-year.

These are the four upper servants of a farm. It is, however, only a large one that requires them all; and even a large one, of the mixed husbandry, may have stone walls, and so be able to dispense with a hedger, an ordinary labourer performing the keeping clean the ditches, &c. Upon smaller farms, the steward sometimes undertakes the hedger's work in addition to his own; the shepherd is sometimes also cattleman; occasionally the steward is steward, hedger, cattleman, and shepherd in one, and sometimes the farmer aids much in these capacities himself, and merely gives one of the ploughmen a little extra pay to act as foreman. Such farms as these last, however, are seldom well cultivated; and it may be laid down as an established fact in farming, that the farmer has enough to do if he undertakes to dispose of the produce, form the general plan of management, and keep up with the advance of agricultural science and practice.

The ploughman is inferior in rank, and receives less wages than any of the above. His duty is to take care of, dress, feed, and work two horses. His work is at the plough, the harrow, the cart, the sowing-machine, and the roller. Upon well-regulated farms he is never apart from his horses,—inasmuch as, if he is working without them, they are costing for their food about two shillings a-day, for which nothing is received. Beyond grooming his horses and doing the work he is told to do—and both these are done under the eye of the steward,—the ploughman has not the slightest responsibility. He receives the same allowance in kind as the steward, but only gets £4 of money. If his wages in kind are commuted for money, his wages amount to from £21 to £26 per annum.

Ploughmen generally receive their education upon small farms, or upon large ones where their fathers are engaged. In either case they receive less wage than a full-grown and competent ploughman. They used formerly, while unmarried, to live in the farmer's house; but in some parts of the country a most reprehensible custom has for long prevailed, of making unmarried ploughmen live in an outhouse, or bothy, as it is called, where they cook their own food, and are, out of work hours, entirely without control; and many evil consequences have been found to result from this plan.

Field-workers are another class of farm-servants. They are usually women in Scotland; and, notwithstanding the prejudice against women working in fields that exists in many parts of England, there can be no doubt but that females make better field-workers than men. Almost all field-work that field-workers have to do, requires not strength but neatness, and are, therefore, better suited to women. The more important of the duties of field-workers are, to single turnips, cut potatoes for seed, gather potatoes, weeding, and so forth; and in the barn they do some of the more important of the operations necessary to prepare corn for the market. Their wage is 10d. a-day.

The dairymaid is more under the control of the farmer's wife, or housekeeper, than the farmer himself; still, she is, properly speaking, a farm-servant. Besides milking, churning, and cheese-making, she attends to the poultry, brings up the motherless lambs, and takes charge of preparing the shearers' food in harvest-time. She receives (besides, of course, her food) about £8 a-year of wages.

Such are the servants of agriculture. The animals necessary for assisting man in cultivating the soil, and the various pieces of machinery and agricultural implements necessary to the farmer, will afterwards claim their due share of attention. All these are necessary for carrying out profitably the *art* of farming. But the time has come when agriculture is something more than an art, depending solely upon isolated facts, transmitted by one generation traditionally to another. For some years past, the *science* of agriculture has had an existence, and is able to teach the farmer those great principles that not only give him a rational explanation of what is going

on around him in his fields and cattle-houses, but which also enable him to introduce new plans and arrangement of details that are shorter, cheaper, and better than the old ones. It becomes, then, necessary to inquire in what the science of agriculture consists.

One of the reasons that the value of agricultural science has been unduly diminished, and that so few have acquired a sufficient knowledge of it, is, that erroneous opinions have been entertained of its nature. For a long time, indeed, it has been known, that, in common with all arts that have to do with matter, which is another expression for saying all arts of which we are cognizant, agriculture can be benefited by a knowledge of the science of mechanics. All farming implements, for instance, from the complicated thrashing-mill to the dung-fork, will do their work with less expenditure of labour when constructed in accordance with sound mechanical principles, than when not so; and, in point of fact, in consequence of farm implements not being constructed in many parts of the country in accordance with such principles, a ton of produce of any kind of crop costs more than it need do to produce. Then the branch of mechanics, called pneumatics, has its bearing upon farming. A farmer requires to understand the barometer—is much the better of knowing the little that is ascertained regarding the weather, or the science of meteorology, as it is termed. These, however, have but little practical influence; and the true science, or rather sciences, that bear upon agriculture, have only been put prominently forward during the past half century, and were but lately, and are not even yet, fully recognised.

The two points in farming upon which the greatest ignorance prevailed, and which yet are the two points upon which it is of the last importance to have exact information, are—1st, What is the precise action and influence of the soil and manure upon plants? and, 2d, What is the precise action and influence of plants when taken into the stomach of animals? At present, the science of agriculture mainly consists in answering these two questions.

It is now a hundred and fifty years ago that Redi pointed out that plants essentially contained a number of inorganic substances. These, we should perhaps say, can be derived from no other source than the soil. But no practical result followed the observations of Redi. At the beginning of the present century, Saussure again directed people's attention to the fact; but still no one appeared to think of applying it to actual farming. The attention of Davy was directed to the chemical composition of both plants and soil; but nothing practical came out of this, and, after his death, the subject was forgotten. Then, still more recently, Mr. Grisenthwaite, of Nottingham, promulgated very clear and precise views upon this subject, which, unluckily, were not attended to. As another has received the honour which of right belongs to this gentleman, we will quote an extract from a work of his, published ten years before Liebig put out his views:—"Let us recur," he says, "once more to the grain of wheat. In that grain there always exists, as has been stated, a portion of phosphate of lime. It is the constancy of its presence that proves beyond reasonable doubt, that it answers some important purpose in the economy of the seed. It is never found in the straw of the plant; it does not exist in barley, or oats, or peas, though grown upon the same land and under the same circumstances, but, as has been just observed, *always* in wheat. Now, to regard this unvarying discrimination as accidental, or to consider it as useless, is to set at defiance the soundest principles of reasoning that philosophy ever bruited. If phosphate of lime had sometimes only been found in wheat, or if it had been discovered in barley or clover, then we might have concluded that the whole was accidental,—that it in no way whatever assisted the formation of the perfect grain, nor contributed to promote the general design of it. They who can oppose these conclusions, will depart from a method of reasoning long established in every department of human knowledge,—a method to which the Baconian philosophy directs us, and to which we must have recourse whenever we are desirous to explain the causes of physical effects. As little attention has hitherto been paid to these saline bodies, at least as they regard the subject of vegetation, and much as they respect the operation of husbandry, I have, for the sake of distinction, called them *specific* manures. Hereafter, when a more complete analysis of vegetables shall be made, it is probable that a nomenclature, founded on their specific substances, may at least classify, if not particularise, every kind of plant. Already we know that there are several vegetables which exercise the power of solution; and it is reasonable to infer, that when investigation shall have more fully laid open the secrets of physiology, that then the uses and designs of this solution will be rendered apparent, and the propriety of regarding it in practical husbandry completely established."

Twelve years ago, Liebig published the fact, that all our common vegetables are composed of various combinations of some thirteen chemical elements; that these elements differ in the proportions in which they unite in the different species; that the different properties and appearances of these vegetables are attributable to these different proportions; and that the art of husbandry mainly consists in supplying to plants a due supply of these elements, which they have the power of appropriating and converting into their own tissues, structures, and organs.

These views of Liebig's have been taught, added to, and amended in this country, by Professor Johnstone and others, and have, unquestionably, increased the productive power and the respectability of agriculture. They have, however, produced less practical effects than might have been expected, and ultimately than they will do. One cause of this is the disposition to use chemistry not so much as a means to an end, but as the end itself. The laws of chemistry are modified in plants and animals by those of physiology; and whoever desires to acquire a satisfactory view of the *science* of agriculture, must investigate these latter. This has been pointed out by Dr. Lindley Kemp, who has written a work upon 'Agricultural Physiology.' We extract from this gentleman's preface the following:—"The art of agriculture, like all other arts, requires for its successful cultivation industry and experience. But in all arts that are cultivated for a long time, there comes a period when the laws of science can be engrafted, as it were, upon the practice of experience, and this to the advantage and improvement of the art. I am aware that there has been, and still is, much difference of opinion as to whether agriculture has reached such a period or not. Many, whose attainments and position give great weight to their sentiments, maintain the latter. But I think that I may venture to affirm, that all those who are acquainted with both physical science and practical agriculture, decide otherwise.

"If it be true that agricultural processes can be more or less influenced and guided by scientific reasonings, it becomes an important question, which science it is that influences the art of agriculture? Many people think that it is chemistry. Chemistry, indeed, is as essential to the study of all mixed physical science as an alphabet is to that of language. It teaches us the nature and properties of the various elementary constituents of bodies, and the laws which regulate their combination in the inorganic or non-vital world. The agriculturist, however, is engaged with organic or vital beings—plants and animals. The combinations and other processes which take place in such are not in subjection to the laws of chemistry, but of another and separate science—that of physiology."

And when we come to answer the second question, viz.: What is the effect and influence of the food upon the animal? we have even more decidedly to trust to physiology. A knowledge of this science, then, with that of chemistry and (for a reason that will be apparent) geology, is the basis of agricultural science. And it is to the union of this agricultural science with capital, and the principle of mercantile industry, that we are to look for the future improvement of agriculture.

Besides physiology, chemistry, and geology, there are other sciences, a knowledge of which is often extremely useful, and always satisfactory to be known by the farmer. Natural history is one of these—especially entomology and botany—inasmuch as the ruin of crops by insects and weeds is often very great; and that by the former has seemed, for some years past,

to have been steadily on the increase. Then the farmer's success depends sometimes upon his being able to foretell the weather. The prognostics of weather are far too empirical: yet still the science of meteorology has an existence, and is often turned to great practical use by the sailor, and might be by the farmer. A certain familiarity with the pathology and therapeutics of cattle, sheep, and horses, is frequently, especially in remote situations, of consequence to the agriculturist. To these we should, perhaps, add an acquaintance with mathematics, sufficiently extended as to enable its possessor to measure land, and draw plans of fields and barns.

## DOMESTIC MEDICINE.

### CHAPTER V.

PHYSICAL CAUSES OF DISEASE—(CONTINUED.)

5. PASSING over the influences of *electric conditions* of the air, and of *atmospheric pressure*, as causes of disease, with the single remark, that Professor Casper, of Berlin, has proved, by observation, that "in nearly all the seasons of the year a high atmospheric pressure increases, and a low pressure (*i. e.* when the mercury in the barometer sinks low) diminishes the rate of mortality;" and recording another of the conclusions of the same distinguished observer, which is in direct opposition to common opinion, "that a humid state of the atmosphere is more favourable to health and life than that which is dry, provided that that humid state be at the same time warm," and that "no state of the atmosphere is so prejudicial to health and life as that of dry cold;"—we come now to the consideration of a most important part of our subject—the effect of *contagion* or *infection*, and of *epidemic* and *endemic influences*, as causes of disease.

Contagion or infection arises from the human body in certain diseased conditions: *endemic* influences originate in poisonous exhalations from the earth's surface; and whether *epidemic* influences originate in the earth or air, or neither—all these noxious effluvia require the atmosphere as a medium of transmission, and may, therefore, be properly included under the head of "atmospheric causes" of disease.

When a disease breaks out suddenly amongst a mass of people, affecting at once a great number of individuals totally unconnected with each other, and when it is altogether impossible to trace its origin to infection, we call that disease an *epidemic*; and of this nature are influenza, catarrhs, &c.

When, on the other hand, a disease begins by affecting an individual here and there, who has, or *may* have, been exposed to infection; when others are similarly affected in proportion to the closeness of their intercourse with these individuals; when the disease proceeds from those primarily affected in any locality, as from so many centres; we are entitled to believe that that disease is communicable from person to person, and we call it *infectious* or *contagious;* and of this nature are typhus fever, scarlet fever, small-pox, &c.

Our remarks in the present chapter will be divided into three heads:—First, *Epidemic Influences*; secondly, *Fevers*, as they appear in a temperate climate; and, thirdly, *Endemic Diseases*, or those arising from *Malaria*.

*First*, then, of *Epidemic Influences;* and, although the above distinction of epidemic and infectious diseases is closely adhered to by many writers, there cannot be a doubt that they are convertible terms; and that a disease may be both epidemic and infectious, or it may have an epidemic origin in the outset, and become infectious in its progress. If such were not the case, why should we have diseases which are undeniably infectious, such as scarlet fever, measles, hooping-cough, so extensively prevalent in some seasons, and not in others—in short, prevailing *epidemically?* Why should we see, as we have frequently done, all kinds of infectious diseases arising spontaneously, and at once, among a number of individuals having no communication between one another, and living widely scattered from each other in rural districts?

Very erroneous and dangerous, although at the same time very plausible, opinions have been taken up and advocated by many eminent medical men regarding epidemic and infectious diseases; and, were it not that the propagation of such opinions is productive of a great amount of evil among the non-professional portion of the public, we would leave them to be embraced or rejected at pleasure. While one party denies the doctrine of infection *in toto*, and, contrary to the recognised principles of all true philosophy, first adopts a theory, and then searches for facts to support it, throwing aside the clearest contrary evidence or explaining it away; another party, taking also a contracted and one-sided view of the question, adheres to the doctrine of infection with the utmost pertinacity, maintaining that, if a disease be infectious, it *can* have no other origin than infection. Nothing can exemplify the truth of these remarks better than the medical evidence on Asiatic cholera, as it has appeared epidemically in this country and abroad. Some observers testify to its non-infectious nature, at the same time they admit that there are numerous instances where cholera has appeared in a place after the arrival of infected persons, and that there are some instances, well authenticated, in which those who came in contact with these newly-arrived and infected persons were the first, or indeed the only sufferers; and these cases indicate, certainly, something more than a mere coincidence. Others of equal ability assert that cholera is propagated solely by infection, although they cannot in any way account for its sudden appearance in many places, where the inhabitants had no communication, either directly or indirectly, with an affected locality. It appears clearly evident that cholera is an epidemic arising from an *unknown something* existing in, and transmitted by, the atmosphere in certain seasons; that it requires for its propagation peculiar concomitant circumstances, and is therefore, in a great measure, confined to localities where these circumstances exist; that the poison giving rise to it is also given off by the bodies of infected persons, existing in a more concentrated form in the air immediately surrounding their bodies, especially if thorough ventilation of the sick-room and the utmost cleanliness be not observed, and thus, although in a limited degree, it becomes a contagious disease.

Typhus fever, scarlet fever, small-pox, erysipelas, measles, hooping-cough, mumps, and Asiatic cholera, yellow fever and plague, all occur epidemically; that is, they break out in certain seasons, and affect large masses of people, without its being possible to trace their origin to contagion; and that they are also all contagious or infectious diseases is equally certain. It was observed, as long ago as the days of Livy, the Roman historian, that even an *endemic* disease, that is, a disease confined to a particular locality, may become contagious. He informs us, that while Marcellus laid siege to Syracuse, B.C. 213 years, the soldiers were placed in a very unhealthy situation, and a pestilence broke out in both armies. "At first," he says, "the unhealthy locality produced sickness and a number of deaths; but afterwards the disease spread by infection, so that those who became affected were neglected or abandoned, and died; or their attendants contracted the disease."* "You can never infer," says Dr. Watson, "that any febrile disorder is not *contagious*, merely because it prevails *epidemically*. Many epidemic diseases are not contagious (?). But the two properties may and do meet in the same malady. They are not to be set in opposition to each other, or regarded as incompatible properties, as they have been by some ingenious writers."†

If the diseases above enumerated were merely propagated by infection, we would naturally expect that they would assume the same form, under similar circumstances, in different seasons; whereas, it is a fact known alike to medical practitioners and to other intelligent observers, that not only does the same disease vary in different epidemics, but that it

* T. Livii Histor. lib. xxv. 26.
† Principles of Medicine, Vol. II., page 660.

is scarcely twice exactly alike. It varies in its symptoms, in its mortality; and the very same disease, as it occurs in different seasons, requires totally different treatment. "Continued fever," observes Dr. Watson, "as it appeared in London during the ten years previous to 1838, required and bore far less depletion than it did for the preceding ten years, or more."

Small-pox often assumes the form of an epidemic, spreading much more rapidly and extensively than it could do if it were only propagated by contagion; this fact, however, is not now so obvious, from the blessing conferred on mankind by vaccination. But Dr. Gregory, physician to the Small-Pox Hospital in London, affirms that not one in twenty cases of small-pox which are sent to him can be traced to any known source of infection. Nay, even a prisoner, shut up in solitary confinement in the Millbank Penitentiary, has been known to be seized with small-pox.

Scarlet fever occurs undoubtedly as an epidemic, and is also, as well as small-pox, highly infectious.

Erysipelas, called also "St. Anthony's fire," and "Rose," was observed even by Hippocrates, the father of medicine, to be epidemic in spring; and from his age downwards, most writers on the subject have mentioned its occasional appearance in an epidemic form. It is often so highly infectious, when it rages epidemically in hospitals, from impure air and other causes, that the surgeons are afraid to perform any operation, on account of the risk of erysipelas attacking the fresh wound.

Measles, hooping-cough and mumps, occur obviously as epidemics, and are also very infectious.

Cholera is almost universally admitted to be an epidemic, but many deny its contagious property. If any one, however, take a calm survey of the facts on both sides of the question, without any infectious or non-infectious theory to obscure his mind and dim his vision, it is next to impossible for him to arrive at any other conclusion than that, although Asiatic cholera be an epidemic, and not very communicable from one person to another, unless that other be placed under unfavourable circumstances, or be predisposed to the disease; still, instances do occur in which, without doubt, cholera is communicated by infection.

What the real cause of epidemics may be, it is impossible, with our present amount of knowledge, to ascertain. Some ascribe them to certain poisonous exhalations arising from the surface of the earth, which, meeting with other concurring causes of disease—such as, peculiar states of the weather, famine, scarcity, unwholesome food, the crowding of a number of persons together, the putrefaction of animal and vegetable substances—thus breed pestilential epidemics. Others ascribe them solely to the influence of the weather, from the circumstance of certain diseases occurring chiefly at particular seasons—thus, we have diseases of the respiratory organs, measles, scarlet fever, &c., in spring; bowel complaints, fevers, small-pox, &c., in summer; cholera, dysentery, &c., in autumn; and inflammations of the chest, rheumatisms, &c., in winter. Others ascribe them to unwholesome and deficient food. Moses relates in Numbers, chap. xi., that the Israelites were seized with pestilence from eating a great quantity of the flesh of quails, which had fallen in immense numbers around their camp, after having been long destitute of animal food. Other writers attribute their origin to animalculæ, or to vegetable germs or fungi, floating in the air; others to a peculiar fluid which escapes from the deep parts of the earth; others to certain electrical conditions of the earth and atmosphere; while some connect their appearance with volcanoes, earthquakes, and comets.

But neither can they be accounted for by poisonous exhalations from the earth's surface; favourable concomitant circumstances are often occurring, and why should these exhalations produce such marked effects at one time and not at another? Nor by the influence of the weather, for cholera and influenza, &c., occur in seasons the most opposite; nor by unwholesome and deficient food; for although, as in the unfortunate case of Ireland a few years ago, this cause will contribute in a most powerful degree to render any fever or epidemic more malignant and fatal, yet it has never been known to originate Asiatic cholera, plague, or even scarlet fever; nor can epidemics be accounted for by the putrefaction of animal substances; for if so, the neighbourhoods of badly kept burial-grounds in large cities would soon be depopulated. As for the other theories above mentioned, they are not only incapable of proof, but they are all deficient in one essential quality of a good philosophical theory —they do not account for the whole of the phenomena.

Breathing an atmosphere vitiated by poisonous exhalations from the earth's surface, from dead and decaying animal or vegetable substances, or from filth and overcrowding; exposure to sudden vicissitudes of weather, to cold and wet; insufficient clothing; famine, and unwholesome food; mental depression; want of sleep; and, above all, debauchery and intemperance—each and all debilitate the system, lower the vital powers, and contribute in a most powerful degree to render the human body not only unable to resist epidemic influences, but the infection of fever, and, in short, every disease to which it is liable. Let any one look around him and see what class of persons are *first* affected by any virulent epidemic or infectious disease, what class are most severely affected, and where are its most numerous victims —among the starving poor, among the dissipated, and in dens and hovels of filth and iniquity. No predisposing cause of epidemic disease, particularly of cholera, has been rendered so apparent as intemperance, or the habitual indulgence in drinking spirituous liquors. In every town and district where that disease made its appearance, it was observed that the *drunkard* was invariably *first* affected, and that his chance of recovery was *least*.

Dr. Watson, in his valuable Lectures on the Principles of Medicine, already quoted, after enumerating several predisposing causes of Asiatic cholera, says—"But to *intemperance*, more than to any other *single cause*, may the proclivity to be affected by this species of cholera be ascribed; and especially to the intemperate and habitual use of distilled spirits. This fact was particularly manifested in the selection, by the disease, of its victims in this country, and it has been remarked almost everywhere else."

The following facts have been ascertained with regard to *epidemic* diseases generally:—

1st, They gradually extend themselves over the surface of the globe, and they have been observed to travel generally in a westward direction: winds retard and aid the passage of the epidemic virus; a strong adverse wind has been noticed to delay the progress of cholera, but not to prevent it.*

2d, They suddenly attack a few of the most predisposed individuals in a city or district, then rapidly reach the height of their virulence; by-and-by they gradually decline; and, in a few weeks or months, they finally disappear.

3d, Although they grow gradually milder in one locality, still, on their first breaking out in another, they assume all their original virulence, if occurring under similar circumstances.

4th, They are generally preceded by a continuance of easterly winds; and are also accompanied or preceded by great extremes of weather.

5th, The lower, the damper, the more confined and filthy the situation, the greater is the virulence of epidemic disease. The choleraic virus has not been observed to ascend to an altitude higher than 6000 feet above the sea level.

6th, It is generally considered that a damp, foggy state of the atmosphere, is indispensable to the transmission of epidemics.

7th, They are frequently preceded by a great amount of disease among the lower animals, as cattle, sheep, &c.

It may appear unprofitable to theorize on "epidemic influences," or to speculate on a subject so obscure as to be incapable of proof; still, the temptation to hazard a conjecture, which seems to account for all the phenomena, is more

* The choleraic virus has been sometimes noticed in India to pass slowly in the *teeth* of the wind; at other times, by the aid of the wind, to acquire a greatly increased velocity.

than we can resist. It may easily be supposed that the globe, as well as the other planets composing the solar system, in their progress through space, must traverse different media. That portion of space through which our earth and atmosphere pass about the middle of November, has been long considered to be filled with substances which, on coming in contact with our atmosphere, explode, and constitute the numerous meteors so frequently observed at that season of the year. The fact of the periodical occurrence of meteoric showers has been observed from the earliest ages downwards; and it is utterly impossible to account for these showers of "falling stars" on any other supposition, than that they are substances floating in space, and explode on coming in contact with our atmosphere. May we not, therefore, suppose it probable that our earth, in traversing space, occasionally comes in contact with substances, not visible meteors, but which can chemically combine with, and invest a portion of the atmosphere, with qualities noxious both to animal and vegetable health and life—causing a fermentation, as it were, as yeast does when added to a warm infusion of malt; that such substances are attracted to certain parts of the earth's surface by their density; and meeting with media favourable for their farther development and propagation—such as the vapour of low and damp localities, filth, putrid animal and vegetable substances—first affect the inferior animals, and give rise to cases here and there of malignant disease amongst human beings; and subsequently, from the continued influence, affect large masses of people with a similar disease, which then gets the name of an *epidemic*. By means of atmospheric currents, such a poison would spread in various directions where it could find circumstances favourable for its transmission; but, in general, by the daily revolution of the earth, its course would be westward; and it would also, by its weight, be most virulent in low, level tracts of country, and become less so the higher the district rose above the level of the sea. This supposition would also account for the gradual extension of epidemics over the surface of the earth; for their decline and disappearance in one district, and their subsequent appearance with equal virulence in another; it might also account for certain epidemics which occasionally appear among the lower animals; and even for the late mysterious disease of the *potato* plant, one remarkable feature of which was, that it occurred for several years in succession, at almost exactly the same period of the year, and is now gradually disappearing.

Whatever truth may exist in the above conjecture, in support of which the want of space prevents us from adducing several additional arguments, it is certain that all pestilential epidemics are preceded by violent commotions in the atmosphere, by great extremes of weather, which has also been observed to follow meteoric showers: this, of course, would likewise affect the quantity and the wholesomeness of food, and account for the fact, that famine and pestilence have, from the earliest ages, been always associated together.

In finishing the subject of epidemic influences by a few practical remarks, it is highly deserving of notice, that the most pestilential epidemic which ever appeared in a temperate climate—the plague—has now been absent for nearly two centuries from those cities of Western Europe which have adopted enlightened sanitary measures. In London and Paris, and several other cities, the good effects of widening and paving streets, of constructing sewers, of introducing a proper supply of fresh water, of draining bogs, of building more airy and better ventilated houses, were immediately visible; while those cities that neglect these means of preservation and self-defence, are still devastated by that fearful malady.

During the occurrence of any epidemic visitation, such as Asiatic cholera, the following preservative measures will be found of the utmost consequence:—

1st, It has been recommended that, to prevent its spreading among the poorer classes, they ought, if possible, to be removed from the close, filthy, and vitiated atmosphere of their habitations to pure air. This would be a very good rule if it were practicable to carry it out. But philanthropy would be much better employed in the gradual elevation of the lower orders in the social scale; in their education, religious and secular; in opening their eyes to the evils of the dram-shop; and in awakening them to a sense of the positive state of misery in which they struggle through a wretched existence, only a few degrees above, if not below, the inferior animals.

2d. During virulent epidemics, the food ought to be carefully attended to, as to quantity and quality; it should neither be too poor, nor too rich and stimulating. A moderate supply of good fresh butcher-meat once a-day, followed (by those who can afford it) by two wine-glassfuls of *genuine* port, is an excellent precaution. During the plague which raged with such violence in London in the seventeenth century, butchers were observed to be remarkably exempt from the disease.

3d. The state of the digestive organs ought to be particularly watched: if the bowels be obstructed, recourse must be had to a dose of castor-oil or of compound rhubarb powder; if relaxed, a dose of tincture of rhubarb, with ten or fifteen drops of laudanum. During the prevalence of cholera, a looseness must be checked *at once* by an astringent mixture.

4th. All the before-mentioned predisposing causes of epidemic disease must be strictly avoided; and to aid in keeping up the vigour of the system, every one ought to wash his whole body once a-day with soap and water, or use the shower-bath, and have a proper supply of clean and warm clothing.

*Secondly, we come to the consideration of* FEVERS.—The general symptoms of an attack of fever from any cause are, first, a cold shivering, great languor and depression of spirits, the person feeling as if some unaccountable load were pressing down his whole body; to these, sooner or later, succeed headache, thirst, heat of skin, pains in the back and limbs, all more or less severe in proportion to the severity of the attack. But as these symptoms are also those of influenza, an attack of inflammation in some important organ, and many other diseases, and as it is impossible for a non-professional person to distinguish the complaint, recourse must be had to competent medical skill.

Fevers, as they exist in this country, may be divided into four classes:—1st, Eruptive fevers; 2d, Common simple fevers; 3d, Symptomatic fevers; and 4th, Typhus fevers.

1st. *Eruptive fevers* are those whose distinguishing feature is a red flush or eruption on the skin, as scarlet fever, measles, &c. Under this head, also, many include our 2d and 4th classes.

2d. *Common simple fever* is that fever which frequently arises in this country from exposure to great vicissitudes of the weather—cold, wet, fatigue, violent mental emotions, &c. It is neither very severe nor very fatal, unless it occur in persons of bad constitutions, and in those highly predisposed to disease. In such cases, it sets up inflammation in some weak internal organ—lungs, bowels, or brain—and is thus very often fatal. If proper precautions be not taken, and if a person be strongly predisposed, it may become infectious, and this in proportion to the malignancy of the case.

3d. *Symptomatic fever* is a fever lighted up in the system by some other disease. In any severe bodily injury, such as fracture of the skull, compound fracture of the limbs—in inflammation of the bowels, lungs, kidney, or other important bodily organ, the system *sympathizes*, as it were, with the diseased organ or texture, fever is excited, and this is called "symptomatic, or sympathetic fever," as being merely a symptom of the primary malady. Of this nature is rheumatic fever and hectic fever, arising from inflammation of certain textures of the body. Symptomatic fever may present all the appearances of simple, or even of typhus fever. In severe cases it frequently affects the patient's brain, producing either a low muttering or a high and furious delirium. Death frequently occurs; and the only differences between this and those other fevers are, that it arises generally from a different cause, and it is *never* infectious.

4th. *Typhus fever* occurs generally as an epidemic, and, in

addition to the symptoms of fevers in general, is peculiarly characterised by sudden and extreme prostration of strength and all the vital powers. The brain is very soon affected, and the mind gets confused and delirious. But perhaps the distinction between common simple fever and typhus fever is more arbitrary than real. Many consider simple fever a mild species of typhus; and simple fever may take on a typhoid form, when it occurs in a bad subject, or under circumstances favourable for the development of typhus, such as in close, confined, and vitiated air, amongst filth, the exhalations from decaying animal or vegetable substances, damp, nakedness, squallor, intemperance, and poverty. In such cases, simple fever assumes all the malignant characters of typhus—is very infectious and fatal.

Some diseases are much more obviously infectious than others; scarlet fever, small-pox, and measles are very infectious. The infection of scarlet fever will lurk among the clothes and furniture of a room for a long time; indeed, unless very efficient means of purifying be resorted to, it is impossible to say at what time there is no danger from infection. Small-pox is so infectious, that instances have occurred in which it, as well as typhus fever, has been caught from the dead body.

Other diseases are not so visibly infectious; such as erysipelas, which, nevertheless, has infectious properties. A direct proof of this once fell under the notice of the writer. An old woman, suffering from some trivial ailment, wrapped a piece of flannel around her head; very soon afterwards she felt a hot prickly sensation in one of her cheeks, which shortly became red and swollen; the redness and swelling extended and increased, and became indeed a very severe attack of erysipelas, or "rose," as she called it. It turned out, on inquiry, that the piece of flannel which she had used had lain in a drawer for six or eight months, and that it had been used before that period by her son-in-law in an hospital, where he suffered a very dangerous attack of erysipelas. No one, who has any sore or abrasure of the skin about the head and face, or who is given to intemperance, ought to have too free intercourse with a person suffering from erysipelas.

Most of the eruptive diseases, and some others, such as hooping-cough and mumps, occur only *once*, as a general rule, in the course of a person's life. But to this rule there are many exceptions, and they have been often known to affect a person a second time, and, in a few instances, even a third time.

The question is often asked, Does an attack of simple fever or of typhus fever render a person less liable to a second attack? and the answer is, that, although in a much less degree, and for a far shorter time, than after such diseases as measles, scarlet fever, and small-pox, still, a person who has undergone an attack of simple or typhus fever is less liable to a second attack, and it is uncommon for him to be affected a second time for a considerable number of years, unless he be highly predisposed to infection, or exposed to its influence in a very concentrated form.

*Predisposing Causes of Fever.*—It has been asserted by some, that unless a predisposition exist on the part of a person exposed to infection—unless the system be in such a state of derangement as to render it unable to resist the morbific influence—that individual is exempt from all danger of the infection of fever. Now, although it is well known that when a person is in full and robust health; when all the bodily organs perform their functions with the utmost perfection and harmony; when he is neither too fat nor too lean; when he is not addicted to ardent spirits, to debauchery, or the depressing passions; when he takes a sufficient amount of exercise in the open air; when the mind is conscious of rectitude and a faithful performance of duty; when the soul is steeled with fortitude and equanimity; then will the vital powers of such a person be enabled to withstand a very powerful morbid impression: still, there *are* cases in which persons have taken fever in robust and vigorous health, without a single *known* predisposing cause in operation, but where they have been exposed to infection for a long time, or for a short time in a very concentrated form. Predisposing causes, however, have a most powerful influence in rendering a person liable to attacks of fever, as well as to almost every other species of disease; and, as we have frequently remarked, *whatever*, either directly or indirectly, *debilitates* the body, will also impair the health, lower the vital energies, and act as a predisposing cause of disease.

Among these debilitating causes may be enumerated, *deficiency of food.* In all ages, famine and disease have been connected like cause and effect. The epidemic and contagious fevers which have so often devastated Ireland, and by which its inhabitants were lately decimated, had their mortality increased to an enormous extent by the inadequate supply, and the unwholesomeness of the food, on which that unfortunate people endeavoured to subsist. Dr. Alison of Edinburgh has proved, that the prevalence and mortality of infectious fevers among the poor, are in direct proportion to their destitution.

Exposure to the *effluvia of overcrowded, filthy, and ill-ventilated dwellings*, and to that arising from the *putrefaction* of dead animal and vegetable substances, are very powerful debilitating causes.

*Grief, anxiety, disappointment, exposure to vicissitudes of weather, fatigue, previous illness, excessive purging, or other secretions or discharges, want of sleep, long-continued watching on a sick bed, intense study, and, above all, sensual excesses and intemperance*, will each sap the strength, depress the vital powers, and, as we have before remarked, render the body an easy prey to the infection of fever, or any epidemic influence.

Nothing, perhaps, has a more powerful effect in predisposing the body to be affected by fever, than the *fear of being affected;* and nothing is found to be so effectual a preservative against the infection of fevers and pestilential epidemics, by medical men and others who are obliged to have intercourse with the sick, as a strong confidence in the protection of a higher Power, a strict adherence to duty, and the banishing from the mind as much as possible all thoughts of danger. This is well exemplified in the case of the "Sisters of Charity," and others imbued with a strong sense of religion, who minister to the sick, and who are very seldom affected by any contagious disease.

Age fortifies the system against infection. Both below and above a certain age the risk is much less, and the chance of escape much greater, as will be seen from the following table, which gives the ages of the patients admitted into the London Fever Hospital for one year:—

| | | | |
|---|---|---|---|
| Under | 10 years, | 18 | admissions. |
| Between | 10 and 15 | 68 | " |
| " | 15 and 20 | 130 | " |
| " | 20 and 25 | 178 | " |
| " | 25 and 30 | 100 | " |
| " | 30 and 35 | 44 | " |
| " | 35 and 40 | 44 | " |
| " | 40 and 45 | 31 | " |
| " | 45 and 50 | 14 | " |
| " | 50 and 55 | 10 | " |
| " | 55 and 60 | 8 | " |
| " | 60 and 65 | 8 | " |
| " | 65 and 70 | 2 | " |
| " | 70 and 75 | 3 | " |
| " | 75 and 80 | 1 | " |
| Ages not ascertained, | | 17 | " |
| | Total, | 676 | admissions. |

Male, ..............324 | Female, ............352

*Precautions to be taken to prevent infection, and to prevent the fever from spreading.*—As a general rule, whenever a case of fever occurs among the poor, the patient ought to be sent at once to a fever hospital, *if possible*, where he will have much better attendance, have a greater chance of recovery, and the fever will be prevented from spreading. This being done, the house ought to be thoroughly ventilated, fumi-

gated,* and whitewashed. If not sent to an hospital, or if the case occur in a family where every convenience for the patient's comfort can be obtained, the following rules ought to be strictly adhered to, both for the safety of the patient and his friends:—

1st. Place the patient in as large an apartment as possible, and, to insure thorough ventilation, have a fire in the room, and a window always open; but if the weather be warm, the fire must be dispensed with, and both the window and door kept open; the air of the room ought to be pure and dry, of an equable temperature, and the patient should be out of the way of currents of wind.

2d. Have dark-coloured blinds upon the windows, and remove the window and bed curtains, carpet, hearth-rug, and all possible articles of furniture from the room, as these would act as nuclei for retaining the infection, and rendering communication with the patient dangerous.

3d. Have the most scrupulous regard to the cleanliness of the patient and that of his apartment. Let him have his body frequently sponged with soap and water; let all his discharges be immediately removed from the room; let his sheets and body linen be frequently changed, and let these soiled clothes be instantly immersed in water.

4th. Let no more people visit him than is *absolutely* necessary, a direction not only useful for the safety of others, but essential for the safety of the patient himself.

5th. Those who attend the patient, ought, if possible, to be upwards of forty years of age; they ought to be very careful to avoid all the above-mentioned predisposing causes; to have good nourishing food, with a moderate supply of butcher-meat daily; to keep their bowels open by *mild* laxatives if necessary, such as rhubarb pills or powder, or castor-oil; to avoid entering the sick-room fasting; not to inhale the effluvia from the patient's breath or his body; and to have a quiet cheerful demeanour in their intercourse with the patient.

The sprinkling of solution of chloride of lime about the room, carrying camphor, &c., are excellent preservatives against infection. But numerous experiments, made for the purpose, prove that, in general, the infectious air only extends but a few feet from the bodies of persons labouring under contagious diseases, *provided* the apartment be *thoroughly ventilated;* that is, at a few feet distant from the patient, the infection is so diluted with atmospheric air as to be almost innocuous, unless a strong predisposition exist. The preservative, therefore, in which we have by far the most confidence, is "FRESH AIR."

It is told of the late Dr. Gregory of Edinburgh, that, on being sent for to fever patients in poor, close, ill-ventilated apartments, with immoveable windows, the first thing he did on entering the room was to smash a pane of glass to pieces with his stick; those who were unacquainted with the Doctor's "*ways*," stared in mute amazement, till he told them that it was to give both them and the patient the incalculable benefit of fresh air, and that this was his first prescription.

*In the third and last place, we have to consider* ENDEMIC INFLUENCES.—When a disease is confined to a certain locality, solely affecting the individuals who reside there, and more especially strangers who frequent that locality, that disease is called *endemic*, from its originating in a local cause; and of this nature is ague, or intermittent fever, arising from *malaria*, or poisonous exhalations from the earth's surface. Nothing whatever is known of the intimate nature of this effluvia; the water and air of affected localities have been examined by all the means which science can suggest, but it still remains one of "nature's secrets." It was long believed to arise solely from marshes, and was called "marsh miasmata:" it was also believed to arise from the decay and putrefaction of animal and vegetable substances; but Spain, the driest country of Europe, and the low and sandy coast of Holland, are much affected with malaria, unconnected with marshes, or a vestige of animal or vegetable decay.

Malaria chiefly exists in low-lying and flat grounds, such as are periodically covered with rains, and afterwards dried up by the heat of the sun; and in proportion to the intensity of this heat, and the rapidity with which the water is dried up, the malaria is the more virulent. It is so virulent in some parts of India, that in certain seasons of the year, during the intense heat after the periodical rains, every living creature must abandon those woods and jungles where malaria abounds. Not so much as a single bird is to be seen till the rains recommence, when man and beast can return with safety. Under the burning sun of the East and West Indies, the fever arising from malaria assumes the character of malignant typhus; in Spain and Italy, it is of the remittent form; while, in the more temperate climate of England, and even in Holland, it is simple ague.

The following facts have been ascertained with regard to malaria and its effects, all of which ought to be carefully borne in mind, and attended to by those living in malarious districts, and by those who may frequent a malarious country:—

1st. With the solitary exception of the African negro, none are exempt from the effects of malaria. Strangers, however, in a malarious district, are much more liable to be affected than natives, or than those who have been some time habituated to the poison. Still, its injurious influence upon the natives is very marked: the race deteriorates; their bodies and minds suffer; they become by degrees smaller in stature, get prematurely old and wrinkled; their spirits get languid, and their intellects become feeble and incapable of mental exertion. Hence the deterioration of the once powerful mental energy of the Spaniards and Portuguese, from the effects of a poisoned atmosphere operating for ages on the human constitution.

2d. Malarious places are always most dangerous after the sun goes down at night, and before he rises in the morning, when the dew is falling. On a ship touching a malarious coast, those of the crew who sleep on shore are sure to be attacked, while those who return to the ship at night escape.

3d. The poison creeps along the surface of the earth, and does not reach high grounds unless blown upwards by the wind. In the soldiers' barracks in Jamaica, three are seized of these who sleep on the ground floor for one on the second, and in Barbadoes two for one.

4th. The malarious poison attaches itself to, and is intercepted by, wood and water; hence the great use of these being placed between affected localities and human habitations.

5th. The production of malaria is prevented by draining and cultivation. Ague was at one time a very prevalent disease in Scotland, where it is now unheard of, and much more common in England than it is at the present day; and there are ample proofs that this circumstance is solely owing to the drainage of bogs, and the improved cultivation of the soil.

Those who have once had ague, ought, wherever they are, to avoid exhaustion and overfatigue, exposure to cold and wet, and to sharp east winds; and they ought to be very careful to change their clothes or shoes when damp or wet. Those who visit a malarious district or country, ought never to go out late at night or early in the morning, or, when obliged to do so, not to go out fasting; they ought to have their dwellings as highly situate as possible, and not built, as many of the West Indian towns are, on the *lee side* of a malarious district; they should sleep in attic rooms, and not near the ground; they ought carefully to avoid all the above-mentioned predisposing causes of fever and epidemic disease, adopting a generous diet, with fermented liquors in moderate quantity. Strangers, on their first visiting a malarious country, are recommended to take small doses of quinine—the great specific medicine for intermittent fever—by way of prevention.

* An apartment is fumigated by placing several saucers, or shallow vessels, filled with common salt moistened with water, in different parts of it, and pouring dilute oil of vitriol upon the salt; the gas which is given off is *chlorine*, and is a very good disinfectant.

## THE SCIENCE OF PHRENOLOGY.

### CHAPTER I.

Objections stated and met—Brain the Organ of the Mind—Duality of the Brain—Congeries of Organs in the Brain—Size of Brain an Index of Power—Comparative Estimate of the Size of Brain in the several Counties of England—Gall's Account of his Discovery—Rules for determining Character by the Shape of the Head—Advantages attending the Study.

In calling the attention of the reader to the science of phrenology, we are not insensible to the difficulties which present themselves at the outset; and we are aware of the odium which some persons may imagine will attach itself to the individual who attempts to lift the veil of antiquity, and to show that the speculations of the schoolmen did not always evince superhuman wisdom. Time has thrown around the classic authors of antiquity the venerable robe of sanctity, and it is almost considered impious to propound any doctrine which carries not with it the stamp of their authority. A little reflection will, however, convince us, that even among the sages of antiquity, new doctrines have ever met with persevering hostility; and the propounders of them have, in some instances, suffered ignominious deaths, or been incarcerated in dungeons, or banished from their country, kindred, and friends. In all ages, the antipathy to what is termed NEW has displayed itself, and those who have laboured the most disinterestedly and the most zealously to instruct mankind, have been those who have suffered most from ignorance. A few illustrations will suffice to prove this.

The intelligence and the virtue of Socrates was punished with death! Anaxagoras, when he attempted to propagate a just notion of the Supreme Being, was dragged to prison! Aristotle, after a long series of persecution, swallowed poison! Virgilius, bishop of Saltzburg, having asserted that there existed Antipodes, the Archbishop of Mentz declared him a heretic! The Abbot Trithemius, who was fond of stenography, having published several curious works on this subject, they were condemned as full of diabolical mysteries: and Frederick II., Elector Palatine, ordered Trithemius's original work, which was in his library, to be publicly burnt. Galileo was condemned at Rome publicly to disavow his sentiments! Cornelius Agrippa was compelled to fly his country, merely for having exhibited a few philosophical experiments, which now every schoolboy can perform! Des Cartes was cruelly persecuted in Holland, where he first published his opinions; while the great geometricians and chemists, Gerbert and Roger Bacon, were abhorred as magicians, and looked upon as objects of horror! This persecution of that which is new, has lost but very little of its virulence in our own time; for, although phrenology is received with much more complacency now than formerly, yet the reader can form but a very imperfect estimate of the obloquy which attached itself to its first promulgation; and the writer can safely say, he has, perhaps, suffered as much as any. Not only was it difficult to obtain an audience to lecture to, but even a room to lecture in; and when the late Dr. Spurzheim, by great interest, procured a hall at the University of Cambridge, he found himself, at the commencement of his lecture, with but one solitary hearer. At present, no such difficulties present themselves to a man of average ability; but still the advocates of the science are often assailed with the epithets of infidels and materialists; and the staple objections to the science now rest principally on these terms. It is contended that the science is hostile to religion; that it is a system of materialism and fatalism; and that the philosophical infidel is its most potent champion. We feel it necessary to examine each of these objections:—

Objection I. *It is hostile to Religion.*—It is true, clergymen have written against it; but, it is presumed, they have done so from a misapprehension of its principles, and, in consequence of such misapprehension, which has generally originated in hearsay, they have not gone into the investigation sufficiently single-minded; and many have condemned it altogether without reading a single volume of the works of its great discoverers. But the objection of a clergyman against the science is no proof of its fallacy. Many clergymen have been warm advocates of its principles. The late Rev. Dr. Welch, professor of Church History in the University of Edinburgh, was the founder of the first Phrenological Society in Great Britain. That society, in the metropolis of Scotland (Edinburgh), still exists, has a large museum and library, and has produced some of the most eminent phrenologists,—the late lamented and amiable Dr. Combe, and his brother, the justly-celebrated George Combe, one of the most profound philosophers of the present day; Robert Cox, Esq., the editor of the *Phrenological Journal;* James Simpson, Esq., the celebrated educationist; Sir G. S. Mackenzie, Bart.; and many others of equal note. Dr. Welch has left a valuable testimony in favour of the science; his own words are:—"I think it right to declare that I have found the greatest benefit from the science, as a minister of the gospel. I have been led to study the evidences of Christianity anew, in connection with phrenology, and I feel my confidence in the truths of our religion increased by this new examination; and, in dealing with my people, in the ordinary duties of my calling, the practical benefit I have derived from phrenology is incalculable."—Further, the present Archbishop of Dublin, Dr. Whateley, one of the most profound scholars, and the most eminent logician of the present day, has declared that the objection brought against phrenology, on the ground of its opposition to religion, is utterly futile, and unworthy any rational mind. Thus, if clergymen have written against the science, eminent and dignified clergymen have written in its favour. But, if phrenology is opposed to religion, how does it happen that the bust describes special religious faculties?—and these, by phrenologists, are absolutely declared to be among the most important powers of the mind. If phrenologists were anxious to overthrow religion (a thing utterly impossible), would they take so much pains to cultivate those sentiments which, by all, are admitted equally indispensable to the well-being of society as well as to the individual man? Why take so much pains to prove that there is a sentiment of Benevolence, or Charity; of Faith, or Marvellousness, which induces a belief in a Supreme Being; of Hope of futurity; of Veneration, or a reverence for the Great Supreme; of Conscientiousness, or a love of integrity and truth; of Ideality, or a love of excellence; and of Firmness, or perseverance in well-doing?—They might at once blot out all these faculties from their authenticated and well-drawn map of the mind, if they were the opponents of religion. But it is well known that the contrary is the case; and phrenology has among its advocates clergymen of talent, and of all religious denominations.

Objection II. *Phrenology leads to Materialism, nay, say its opponents,* is *Materialism.*—It cannot be denied that there are some phrenologists who so contend, but there are enow of us who protest against it. It is scarcely possible to conceive how such a charge can be sustained. The mind may easily be proved to act by material organs, but this does not prove the mind itself to be material. Phrenologists do not deny that the mind communicates in some mysterious way with the brain; they only say they cannot tell how. Will our opponents enlighten our darkness by informing us? if they cannot, why do they blame us for that for which they have no solution themselves? Matter, whether in its more gross or etherealised form, is matter still; and if it could possess any of the attributes of spirit, it would cease to be matter. The brain itself does not think, and phrenologists—at least the majority of them—have never contended that it does. They have never pretended to show in what manner spirit becomes united with matter; nor is it necessary they should. To those who believe in Divine Revelation, it is quite easy to prove that spirit can and does exist without matter; but as this is a question pertaining to theology, of course it cannot be discussed here.

Objection III. *Phrenology leads to Fatalism.*—Now, fatalism literally implies that man is a passive being; that he has no will of his own, but is acted upon by a power he is incapable of resisting.

Phrenology has no such tendency. If one organ is in excess, there are others which may be brought to bear upon it, to restrain it and keep it in order. If one organ is defi-

cient, by commencing its cultivation at a proper period, there is proof that its power can be increased; and there are also other powers which may be called in to aid, and, in some degree, to compensate for, its weakness. But this no more implies fatality, than the case of the servant mentioned in the gospel, who received his lord's money to trade with. The man that had but one talent was not condemned because he had but one, but because he did not make use of that one. But we contend that it is quite possible to alter and improve the organization, if commenced at a proper period of life. Richard Beamish, Esq., F.R.S., in a lecture delivered some time since, at the Town-hall, Buckingham, states, that his own head had so much changed by two years' hard study, as to render the casts taken of him at several previous periods scarcely recognisable as belonging to the same individual; and such is also the case with respect to the writer of this paper. Human responsibility is undoubted, and is fully admitted by phrenologists; but, in cases of insanity, it is impossible to hold a man responsible.

It is urged further, as an insuperable objection to phrenology, that cases have been well authenticated, in which the brain has been injured, altered in structure, and even partially destroyed, while the mind has continued unimpaired, and carried on its operations with its accustomed regularity. It should, however, be borne in mind, that the organs of the brain, like the other organs of the animal economy, are double; and therefore, as one eye may be lost, and the faculty of sight remain perfect in the other, so one organ, or one set of organs, may be diseased or even destroyed, while the functions of the brain may still be performed with the other. A very interesting proof of the duality of the brain is given in the *Phrenological Journal* (vol. x.), which we will cite:—

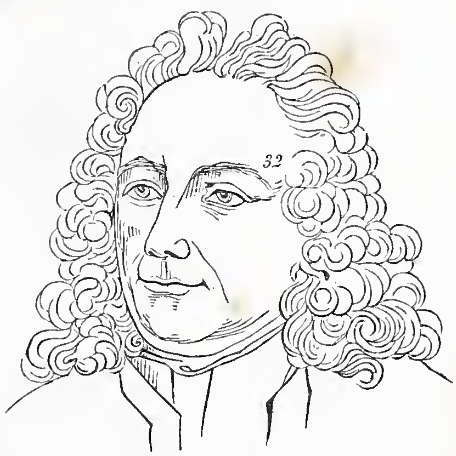
"Mr. S. dreamed that he was in his parlour with a friend, and that a piece of *black cloth* was lying on the table, but which his friend happened to remark was flesh-coloured. Hereupon arose a discussion as to the colour of the cloth, Mr. S. maintaining that it was black, and his friend as strenuously insisting that it was flesh-coloured. The dispute became warm, and Mr. S. offered to bet that it was black; his friend also offering to bet that it was flesh-colour. Mr. S. concluded the bet, when his friend immediately exclaimed, 'And is not black the colour of more than half the human race?'—thus completely stealing a march upon Mr. S., and winning the bet. Mr. S. declares that the idea of black being flesh-colour never occurred to him. The extraordinary part of this dream is, that two operations were going on at the same time, and in the same mind—the workings of the one apparently quite concealed from the other. For instance, the part of the brain which personated himself had no knowledge whatever of the loop-hole which the part of the brain personating his friend had in reserve to close the argument. On the contrary, Mr. S. says he was utterly abashed by the remark, immediately thinking to himself how foolish he was not to have been in possession of the idea, and this very vexation caused him to awake."

It is thus proved the brain is dual. But the brain, besides being dual, consists of a congeries of organs, and this is easily demonstrable. If the brain were a single organ, then the idea of the metaphysicians that the mind is a *tabula rasa* would be correct, and educators would have it in their power to form the statesman, the lawyer, the divine, or the architect, the painter, the sculptor, as the wishes and the means of the parent might direct. But we every day see the reverse of this, and different individuals are biassed to various pursuits, as their organization seems to impel them. If we walk the streets of large towns as observers of others, we shall perceive the multitude attracted by different objects. While the tradesman is attracted by the stock of his brother in trade, and the taste with which it is displayed to attract the eye of the public, the student will be found at the bookseller's; and while the mechanic is observing with attention tools and machinery, the artist will be attracted by the printseller.

But if all men were similarly organized, the same attractions would arrest the attention equally of all. It is true, that as all minds possess that in common which makes them human, they acquire, to a certain extent, the same *general* development; but each mind possesses something peculiar to itself, which disposes it to a course of action distinctly different to that of any other; and this, surely, is one of the most beneficent arrangements of the Supreme, endowing different individuals with different powers or faculties, that each may minister to the general good of the whole:—

"Some at the sounding anvil glow;
Some the swift-sliding shuttle throw;
Some, studious of the wind and tide,
From pole to pole our commerce guide;
Some, taught by industry, impart
With hands and feet the works of art;
While some, of genius more refined,
With head and tongue assist mankind.
* * * * * *
The monarch, when his table's spread,
Is to the clown obliged for bread;
And, when in all his glory dress'd,
Owes to the loom his royal vest.
Does not the mason's toil and care
Protect him from th' inclement air?
Does not the cutler's art supply
The ornament that guards his thigh?"
* * * * * *

The same may be affirmed of everything connected with taste and art, and the bias displays itself almost invariably in infancy—at least long before reflection leads to what is called the choice of a profession. The first development of the musical genius is while yet an infant. The harmony of sweet sounds not only catches the ear, but excites the desire to produce similar sounds. The celebrated violinist, Paganini, began his career as soon as he was able to hold the instrument. Is there any incongruity in supposing that this desire should manifest itself by some external development? Here is a portrait of HANDEL:—




Let the reader examine well the lateral parts of the forehead, where the No. 32 is marked, and he will observe them much enlarged; and, as he passes the shop-window of the musicseller, let him observe the lateral parts of the forehead of the portraits of those eminent composers, frequently exhibited, and he will find them all freely and fully rounded. The late Madame Catalani and the present Jenny Lind have these portions of the forehead beautifully developed.

Handel's father was a physician at Halle, in Saxony, and destined his son for the profession of the law; and, seeing his early predilection for music, determined to check it. He excluded from his house all musical society, nor would he permit music or musical instruments to be ever heard within its walls. The child, however, notwithstanding his parents' precautions, found means to hear somebody play on the harpsichord; and the delight which he felt having prompted him to endeavour to gain an opportunity of practising what he heard, he contrived, through a servant, to procure a small clarichord or spinnet, which he secreted in a garret, and to which he repaired every night after the family had gone to

rest. Mr. Hogarth, in his popular "History of Music," has the following observation:—"A childish love for music or painting, even when accompanied with an aptitude to learn something of these arts, is not, in one case out of a hundred or a thousand, conjoined with that degree of genius, without which it would be a vain and idle pursuit." But as phrenology will enable us to judge of the capability by the organization, if we will but appeal to it, to abide by what Mr. Hogarth advises, is to hide under a bushel that light which might serve to illuminate the whole hemisphere of that particular department of art; and we say to parents, that where, as in the case of Handel and West, (mentioned just below,) music and painting develop themselves at nine years of age, and in defiance of all the difficulties opposed to them, cultivate respectively such talents: such children are public benefactors in embryo, and the parents may live to behold them arise to eminence.

It is the same with painting. The infant painter no sooner sees the effect produced by the pencil, than the will impels him to grasp the tiny tool, that he may gratify his love of the art by attempting to sketch a picture for himself. Is it too much to say that this love will develop itself by some striking external development? The late Benjamin West, the son of Quaker parents, who prohibit, by their discipline, the cultivation of the arts, yet gave indications of his talent for drawing in his ninth year. It is thus that the latent talents of the soul, as they expand under proper culture, and sometimes in defiance of it, acquire the gratification and delight after which they pant; and it is not more difficult for the tree to return to the seed from whence it sprung, than for the person so endowed to cease to act. The soil which produces the vine, in its most healthy luxuriance, is not better adapted than the world we live in, to draw forth and mature the latent energies of the soul, and fill them with life and vigour. Is there ought in eloquence that warms the heart? she draws her fire from natural imagery. Is there ought in poetry to enliven the imagination? in natural imagery lies the secret of her power; and he who possesses an expansive ideality, with faculties in combination to give scope to its sublimity, will throw the rays of his genius over apparently the most unseemly objects!

It may be as well to remark here, that we are accused of having the head mapped out into too many and too minute portions. But, if the writings of the metaphysicians be consulted, it will be found that they enumerate quite as many. But we shall prove, as we proceed, that the phrenologists assign no more powers to the mind than experience demonstrates the absolute existence of. And if they assign to certain portions of the brain faculties, whose functions display various powers, it is because they are possessed of abundant facts to demonstrate what they assert.

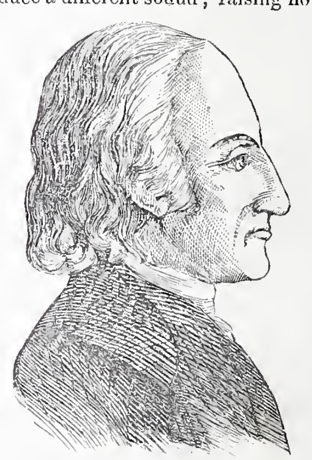
We conclude this part of our inquiry, by affirming that phrenology is a true science of mind; that the brain, as a whole, is the organ of the mind; that the brain is dual; and that there exists a congeries of organs.

We proceed now to show that the size of the brain, other conditions being equal, is an index of power. On dissecting the head of the late Baron Cuvier, the most remarkable feature was the great size of the brain.

"Semmering," says M. Berard, "computes the weight of the human brain to be from two to three pounds." I arrived at the same conclusion, by taking two brains: the one from a woman, aged thirty, weighed, with its membranes, 2lb. 11oz. 2drs.; the other, from a man, aged forty, weighed 2lb. 12oz. 6$\frac{1}{2}$drs. The brain of Cuvier weighed 3lb. 10oz. 4$\frac{1}{2}$drs., being nearly a pound heavier than the weight of the others. But that which is most interesting to the phrenological investigator, is, upon comparing the weight of the cerebellum with that taken from the man just mentioned, a difference of one dram and a half only was found in favour of Cuvier: hence it followed, that the excess of weight in his brain was distributed almost to the cerebral lobes, as the seat of the intellectual faculties.

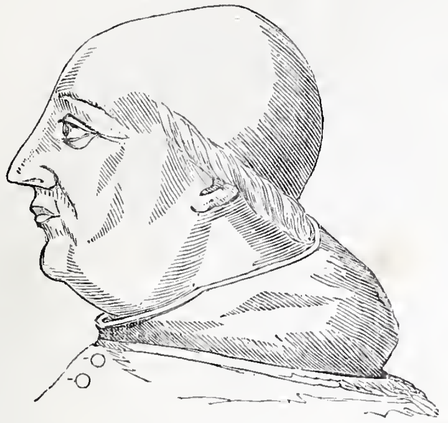
The comparative estimate respecting the dimensions of the heads of the inhabitants in several counties in England is as follows:—The male head in England, at maturity, averages from 6$\frac{1}{2}$ inches to 7$\frac{3}{8}$ in diameter; the medium and most general size being 7. The female head is smaller, varying from 6$\frac{3}{8}$ to 7 (or 7$\frac{1}{2}$ the medium male size). Fixing the medium of the English head at 7, there can be no difficulty in distinguishing the portions of society above, from those below, that measurement. In London, the majority of the higher classes are above the medium; while among the lower it is very rare to find a large head. The Spitalfields weavers have extremely small heads, 6$\frac{3}{8}$, 6$\frac{1}{2}$, and 6$\frac{3}{4}$ being the prevailing admeasurement. In Coventry, almost exclusively peopled by weavers, the same facts are peculiarly observed. Hertfordshire, Essex, Suffolk, and Norfolk, contain a larger proportion of small heads than any part of the empire. Seven inches in diameter is here, as in Spitalfields and Coventry, quite unusual—6$\frac{3}{8}$ and 6$\frac{1}{2}$ are more general; and 6$\frac{3}{8}$, the usual size of a boy of six years of age, is frequently to be met with here in the full maturity of manhood. In Kent, Surrey, and Sussex, an increase of size of the usual average is observed, and the inland counties, in general, are nearly upon the same scale. In Devonshire and Cornwall, the heads are of full size. Herefordshire is superior to the London averages. In Lancashire, Yorkshire, Cumberland, and Northumberland, there are more large heads in proportion than any part of the country. In Scotland, the full-sized head is known to be possessed by the inhabitants: their measurement ranging from between 7$\frac{3}{4}$ to 7$\frac{7}{8}$, and even to 8 inches, of which the writer of this paper has seen many. From this it may be safely inferred that size of brain is an index of power. This fact extends to individual organs and regions, as well as to the whole brain.

We will now show how the brain exercises its power, and through what medium, by a simple analogy:—If we blow through the mouthpiece of a flute, we produce a certain sound. Putting the pieces of the flute together, and placing the fingers on the holes, we produce a different sound; raising now one finger, and then another, by different combinations of stopping we produce a complete harmony. This, however, is not the result of different air or wind, but of the same wind issuing through different channels. So the mind, acting upon different regions of brain, according to the power or quantity of brain in the region on which it operates, produces different results. Acting on the upper or coronal surface of the head, it produces the religious and moral sentiments, as in this portrait of Oberlin. Acting on the posterior part of the head, it exhibits the power of the lower or animal propensities, as in the portrait of Pope Alexander VI., on next page. Acting on the fore part of the head, it exhibits the power of the intellectual faculties, as in the portrait of Spurzheim. But this is only a general view of the character of the respective persons, from the predominance of brain in each region. Besides this, it must be stated that every organ has a power and functions peculiarly its own, subject, however, to the modifying influence of temperament. This modifying influence, and the power and functions of the respective organs, we shall illustrate as we proceed.



It now becomes necessary to say a few words on the discovery of the principles on which this science is based; and, in so doing, we will condense the account given by Dr. Gall himself, observing, however, by the way, that though he possessed eminent powers of reflection, he was but moderately endowed with the perception of *form* and size, and hence almost all his discoveries were from extreme cases. Spurzheim, on the contrary, who became associated with him in 1804, in addition to excellent powers of reflection, had large form and size, a very large brain, and perhaps the keenest general perception

of any phrenologist either during or since his time, and his discrimination of character was amazingly quick and accurate.

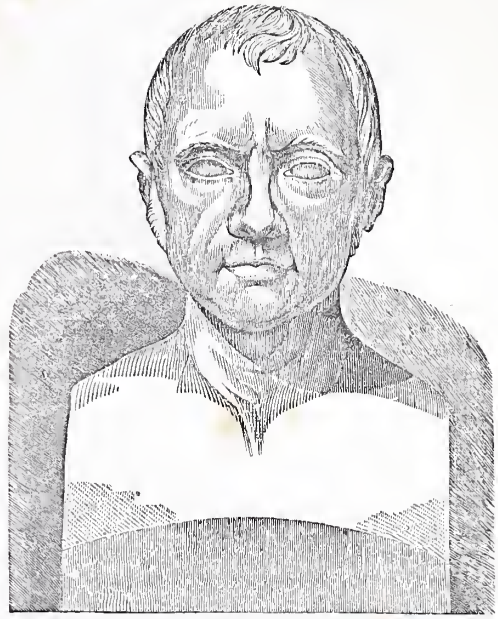


POPE ALEXANDER VI.

To predicate character is not so easy a matter as many have imagined; for though the situation of the organs on the head must, on all occasions, be the same, still, as the size and formation of the head vary in almost every instance, of course the organs will be higher up or lower down than an unpractised person supposes. Then, again, the powers of the mind blend so closely with each other, and different shades of character, originating in different portions of the brain, many errors are likely to arise by a careless manipulator:—the functions of the organ of Secretiveness are liable to be mistaken for those of Cautiousness; Combativeness for Destructiveness; Adhesiveness for Benevolence; and *vice versa*. But to return to the discovery of the science.* Here are portraits of GALL and SPURZHEIM—two noble heads, but still differently excellent:—

GALL.

From an early age, Gall was given to observation, and was struck with the fact, that each of his brothers and sisters, companions in play, and school-fellows, possessed some peculiarity of talent or disposition, which distinguished him from others. Some of his schoolmates were distinguished by the beauty of their penmanship, some by their success in arithmetic, and others by their talent for acquiring a knowledge of



SPURZHEIM.

natural history or of languages. The compositions of one were remarkable for elegance, while the style of another was stiff and dry; and a third connected his reasonings in the closest manner, and clothed his argument in the most forcible language. Their dispositions were equally different, and this diversity appeared also to determine the direction of their partialities and aversions. Not a few of them manifested a capacity for employments which they were not taught; they cut figures in wood, or delineated them on paper. Some devoted their leisure to painting, or the culture of a garden, while their comrades abandoned themselves to noisy games, or traversed the woods to gather flowers, seek for bird's nests, or catch butterflies. In this manner each individual presented a character peculiar to himself, and Gall never observed that the individual who had in one year displayed selfish or knavish dispositions, became in the next a good and faithful friend.

The scholars with whom young Gall had the greatest difficulty of competing were those who learned by heart with great facility, and such individuals frequently gained from him, by their repetitions, the places which he had obtained by the merit of his original compositions. Some years afterwards, having changed his place of residence, he still met individuals endowed with an equally great talent of learning to repeat. He then observed that his school-fellows so gifted possessed prominent eyes, and he recollected that his rivals in the first school had been distinguished by the first peculiarity. When he entered the university, he directed his attention from the first to the students whose eyes were of this description, and he soon found that they all excelled in getting rapidly by heart, and giving correct recitations, although many of them were by no means distinguished in point of general talent. This observation was recognised also by the other students in the classes; and although the connection between the talent and the external sign was not at this time established upon such complete evidence as is requisite for a philosophical conclusion, yet Dr. Gall could not believe that the coincidence of the two circumstances thus observed was entirely accidental. He suspected, therefore, from this period, that they stood in an important relation to each other. After much reflection he conceived, that if memory for words was indicated by an ex-

* This account is condensed from the 'Edinburgh Phrenological Journal,' and the 'Journal de la Société Phrénologique de Paris.'

ternal sign, the same might be the case with the other intellectual powers, and from that moment all individuals distinguished by any remarkable faculty became the objects of his attention. By degrees, he conceived himself to have found external characteristics which indicated a talent for painting, music, and the mechanical arts. He became acquainted, also, with some individuals remarkable for the determination of their character, and he observed a particular part of their heads to be very largely developed. This fact first suggested to him the idea of looking to the head for signs of the moral sentiments. But in making these observations he never conceived, for a moment, that the *skull* was the cause of the different talents, as has been erroneously represented—he referred the influence, whatever it was, to the brain.

In following out, by observation, the principle which accident had thus suggested, he for some time encountered difficulties of the greatest magnitude. Hitherto he had been altogether ignorant of the opinions of physiologists touching the brain, and of metaphysicians respecting the mental faculties, and had simply observed nature. When, however, he began to enlarge his knowledge of books, he found the most extraordinary conflict of opinions everywhere prevailing, and this, for the moment, made him hesitate about the correctness of his own observations. He found that the moral sentiments had, by an almost general consent, been consigned to the thoracic and abdominal viscera; and that, while Pythagoras, Plato, Galen, Haller, and some other physiologists, placed the sentient soul, or intellectual faculties, in the brain, Aristotle placed it in the heart, Van Helmont in the stomach, Des Cartes and his followers in the pineal gland, and Drelincourt and others in the cerebellum.

He observed, also, that a great number of philosophers and physiologists asserted, that all men are born with equal mental faculties, and that the differences observable among them are owing either to education, or to the accidental circumstances in which they are placed. If all differences are accidental, he inferred that there could be no natural signs of predominating faculties, and consequently, that the project of learning by observation to distinguish the functions of the different portions of the brain must be hopeless. This difficulty he combated by the reflection, that his brothers, sisters, and school-fellows, had all received very nearly the same education, but that he had still observed each of them unfolding a distinct character, over which circumstances appeared to exert only a limited control. He observed, also, that not unfrequently they whose education had been conducted with the greatest care, and on whom the labours of teachers had been most freely lavished, remained far behind their companions in attainments. "Often," says Dr. Gall, "we were accused of want of will, or deficiency in zeal; but many of us could not, even with the most ardent desire, followed out by the most obstinate efforts, attain, in some pursuits, even to mediocrity; while, in some other points, some of us surpassed our school-fellows without an effort, and almost, it might be said, without perceiving it ourselves. But, in point of fact, our masters did not appear to attach much faith to the system which taught the equality of the mental faculties, for they thought themselves entitled to exact more from one scholar, and less from another. They spoke frequently of natural gifts, or of the gifts of God, and consoled their pupils in the words of the gospel, by assuring them that each would be required to render an account only in proportion to the gifts which he had received." *

Being convinced by these facts, that there is a natural and constitutional diversity of talents and dispositions, he encountered in books still another obstacle to his success in determining the external signs of the mental powers. He found that, instead of faculties for languages, drawing, memory for places, music, and mechanical arts, corresponding to the different talents which he had observed in his school-fellows, the metaphysicians spoke only of general powers, such as perception, conception, memory, imagination, and judgment. And when he endeavoured to discover external signs in the head, corresponding to these general faculties, or to determine the correctness of the physiological doctrines regarding the seat of the mind, as taught by the authors already mentioned, he found perplexities without end, and difficulties insurmountable.

* Preface, by Dr. Gall, to the "Anatomie, &c., du Cerveau."

Dr. Gall, therefore, abandoning every theory and preconceived opinion, gave himself up entirely to the observation of nature. Being physician to a lunatic asylum in Vienna, he had opportunities, of which he availed himself, of making observations on the insane. He visited prisons and resorted to schools; he was introduced to the courts of princes, to colleges and the seats of justice, and wherever he heard of an individual distinguished in any particular way, either by remarkable endowment or deficiency, he observed and studied the development of his head. In this manner, by an almost imperceptible induction, he conceived himself warranted in believing, that particular mental powers are indicated by particular configurations of the head.

Hitherto he had resorted only to physiognomical indications, as a means of discovering the functions of the brain. On reflection, however, he was convinced that physiology was imperfect when separated from anatomy. Having observed a woman of fifty-four years of age, who had been afflicted with hydrocephalus from her youth, and, with a body a little shrunk, possessed as active and as intelligent a mind as that of other individuals of her class, Dr. Gall declared his conviction that the structure of the brain must be different from what was generally conceived—a remark which Tulpius also had made on observing a hydrocephalus patient, who manifested the mental faculties. He therefore felt the necessity of making anatomical researches into the structure of the brain.

In every instance, when an individual whose head he had observed while alive, happened to die, he used every means to be permitted to examine the brain, and frequently did so; and he found, as a general fact, that on removal of the skull, the brain covered by the *dura mater* presented a form corresponding to that which the skull had exhibited in life.

The successive steps by which Dr. Gall proceeded in his discoveries, are particularly deserving of attention. He did not, as many have imagined, first dissect the brain, and pretend by that means to have discovered the seats of the mental powers. Neither did he, as others have conceived, first map out the skull into various compartments, and assign a faculty to each according as his imagination led him to conceive the place appropriate to the power. On the contrary, he first observed a concomitance between particular talents and dispositions, and particular forms of the head; he next ascertained, by removal of the skull, that the figure and size of the brain are indicated by these external forms; and it was only after these facts were determined, and the brain was minutely dissected, that light was thrown upon its structure.

Although it is impossible to form a correct judgment of the particular character or disposition of a person from observing one organ, or one set of organs, yet a general idea may be formed by observing the contour of the whole head, by observing the following rules:—

1. A very small head is indicative of idiocy, partial or general.

2. A small head, formed in good proportion, indicates capability for discharging ordinary duties; but incapacity for filling any commanding situation, from deficiency of power.

3. A narrow or oval head, elongated at the occipital region, will be found to indicate a warm, friendly, and affectionate disposition, as in the female.

4. A narrow head, elevated at the coronal surface, is indicative of a moral and benevolent character. (See OBERLIN, p. 474.)

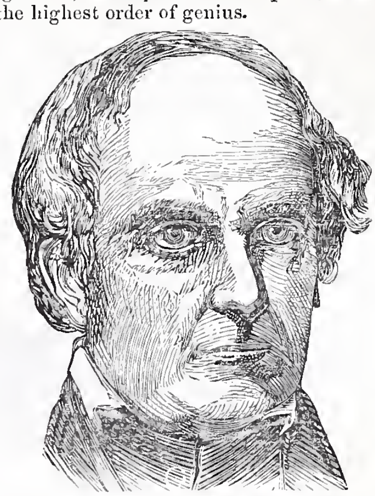
5. A head, round and narrow, is indicative of a quarrelsome and irascible disposition.

CARRACALLA.

6. A head well developed in the forehead, is indicative of an intellectual character.

ELIHU BURRITT.

7. A large head, developed in all its parts, is indicative of a mind of the highest order of genius.

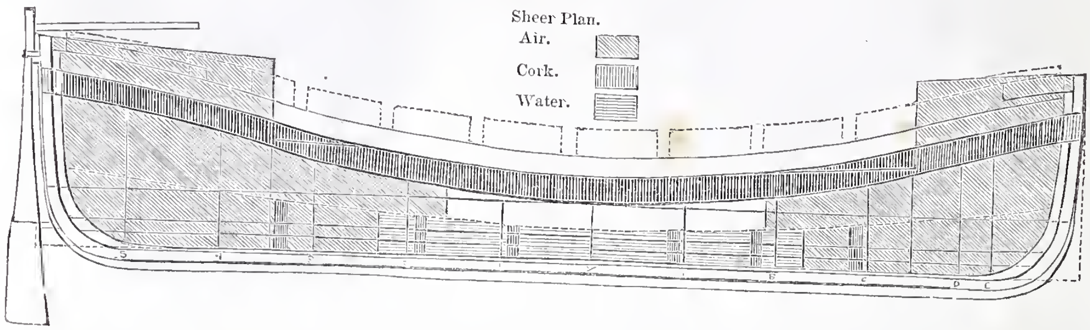


DANIEL WEBSTER.

We must now conclude this introduction to our subject, and we do so by exhorting the student to commence and persevere, and observe for himself—and let him begin with himself—let him not be deterred by the fear of ridicule. Let him take the advice of the writer, who has for thirty-one years, at much loss, and under much censure, pursued his investigations—in a great measure trained himself by its principles, and also trained and educated his family successfully, seeking for them those employments which best suited their organization. In his surviving family, he can enumerate a skilful physician, an excellent practical engineer, a good chemist, and a clever musician. Perhaps the reader may not have had the advantage of a phrenological parent; let him then commence the study and education of himself. In a 'Tour by a Lady through the Upper Provinces of Hindostan,' is the following anecdote:—"The Hindoos never, if they can avoid it, forsake the trade of their fathers, and are tenacious even in improving it. I once asked a baker to make muffins, and offered to translate a receipt I had for them into Hindostanee, promising him, at the same time, a recommendation to all my acquaintance, which was large, being at the principal military station. He listened very attentively till I had finished my speech, when, closing his hands in a supplicating posture, he said, 'Pardon me, lady, but my father never made them, my grandfather never made them, and how can I presume to do it? My grandfather brought up sixteen children, my father fourteen, without baking *mufkeens*, and why should not I?'" The reader will not, surely, imitate this Hindoo, but having become his own master, remember that it is left to himself to complete his own education; for the formation of his character while under the control of others, he is by no means accountable, but when he is freed from all restraint, deep responsibility is entailed upon him. He has taken the guidance of a human being, and he is not the less accountable that this being is himself. The ligament is now cut asunder by which his mind was bound to its earthly guardian, and he is placed on his own power, exposed alike to the bleak winds of persecution, and to the gentle breezes of perseverance, fully accountable for his conduct to both God and man. Let him not be made dizzy from a sense of his own liberty, nor faint under the weight of his own responsibility; but let him remember, that while the eye of his Father is upon him, his words are, "Occupy till I come." Let him find out the extent of his own powers, and seek to direct them into their proper channels; and to assist him in this important work, let him take phrenology to his aid—there is no science better adapted to make him acquainted with himself. He may by this science be brought to see, that this natural world is one vast mine of wisdom, and this world he may discover a miniature existence of within; in observing which he will become soundly philosophical, and in loving which he will become rationally religious.

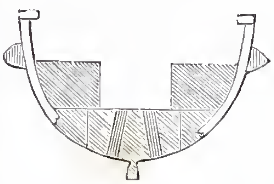
## LIFE-BOAT.—THE NORTHUMBERLAND PRIZE.

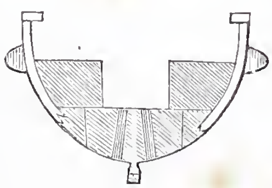
The Northumberland prize for the best life-boat was gained by Mr. James Beeching, boat-builder, of Great Yarmouth. The various models of competitors occupied compartment Class VIII., No. 136, of the Great Exhibition. In consequence of the numerous accidents which, for a series of years, had happened to life-boats around the coasts, and more especially that deplorable case which occurred in December, 1849, when, by the upsetting of a life-boat off Shields, twenty of the best pilots in England were drowned, his Grace the Duke of Northumberland, in October, 1850, offered a prize




of one hundred guineas for the best model of a life-boat. The result was, that 280 models and plans were sent to Somerset House for competition, and the documents collected or contributed, in consequence of this humane offer on the part of his Grace, fill five folio manuscript volumes. These will be found a valuable record for reference in future inquiries.

Section at 3.

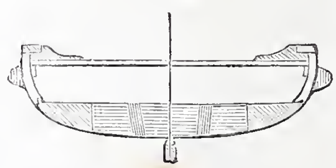


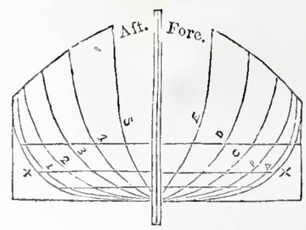


Section at C.

Among so many models, it was not without great difficulty that one was selected for the prize. It was not till the six that stood first in the list had been placed side by side for the third time, and their different peculiarities and points of excellence carefully examined and compared, that the premium for the best model was awarded to Mr. James Beeching. The elaborate examination which was necessary for this decision has imparted a peculiar value to the committee's report, which is a document of very great interest: the requisite qualities of a life-boat are set forth; the peculiar features of several of the best models detailed; the accidents to life-boats, and number of shipwrecks on the coasts of the United Kingdom enumerated; the life-boat, rocket, and mortar stations given, and various important suggestions thrown out for decreasing the number of wrecks, life-boat accidents, &c. In the latter case, however, a life-boat of proper construction is regarded as the most efficient security, and the general adoption of the plan of construction of the prize boat is highly recommended for this purpose. We give a detailed engraving of its several parts and proportions, the principle of which will be best understood by the following official description of the committee:—

Section at ⊗

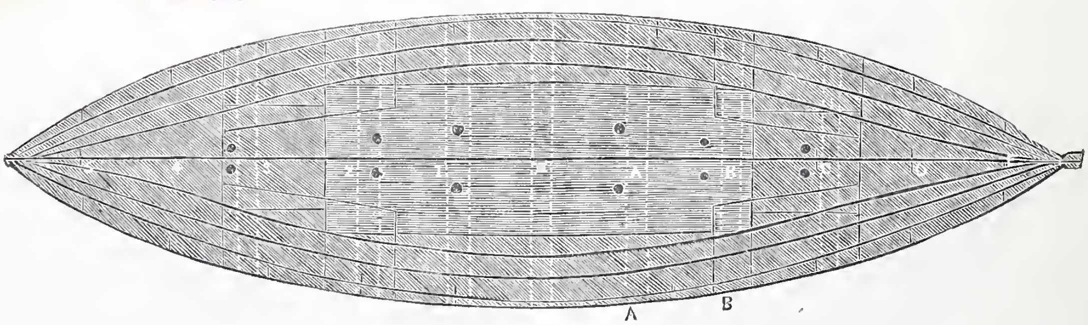





Body Plan.

"The body of this boat is of the form usually given to a whale boat—a slightly rounded floor, sides round in the fore and aft direction, upright stem and stern-post, clench-built, of wainscot oak, and iron fastened.

"Length extreme, 36 feet; of keel, 31 feet; breadth of beam, 9½ feet; depth, 3½ feet; sheer of gunwale, 36 inches; rake of stem and stern-post, 5 inches; straight keel, 8 inches deep. The boat has seven thwarts 27 inches apart, 7 inches below the gunwale, and 18 inches above the floor; pulls 12




A, Water tank.
B, Air-tight deck; the spaces below are divided into air-tight compartments.
C, Diagonal air-tight cases.
D, Air-tight seats, enclosing air-tight compartments for dry provisions.
E, Tubes with valves for emptying the water out through the bottom.
F, Screw valves to admit water into the tank A.
G, A belt of cork.
H, A pump to draw water out of the tank.
I, Compass.
K, Inner skin, air-tight.

oars, double-banked, with pins and grummets. A cork fender, 6 inches wide, by 8 inches deep, runs round outside at 7 inches below the gunwale.

"Extra buoyancy is given by air-cases, 20 inches high in the bottom of the boat under the flat; round part of the sides, 24 inches wide by 18 inches deep, up to the level of the thwarts, leaving 10 feet free amidships; and in the head and stern sheets, for a length of $8\frac{1}{2}$ feet, to the height of the gunwale; the whole divided into compartments, and built into the boat; also by the cork fenders. Effective extra buoyancy 200 cubic feet, equal to $8\frac{1}{2}$ tons. For ballast, a water-tank divided into compartments, placed in the bottom amidships, 14 feet long by 5 feet wide and 15 inches high, containing 77 cubic feet, equal to $2\frac{1}{4}$ tons when full, and an iron keel of 10 cwt. Internal capacity of boat under the level of the thwarts, 176 cubic feet, equal to 5 tons. Means of freeing the boat of water, tubes through the bottom, 8 of 6 inches diameter, and 4 of 4 inches diameter—total area, 276 square inches, which is to the capacity in the proportion of 276 to 176, or as 1 to ·64. Provision for righting the boat if upset, $2\frac{1}{2}$ tons of water-ballast, an iron keel, and raised air-cases in the head and stern sheets. Rig, lug foresail and mizen; to be steered by a rudder; no timber heads for securing a warp to. Draft of water, with 30 persons on board, 26 inches. Weight of boat, 50 cwt.; of gear, 17 cwt.; total, 67 cwt. Would carry 70 persons. Cost, with gear, £250.

"The form given to this boat would make her efficient either for pulling or sailing in all weathers—she would prove a good sea-boat; and in places such as Yarmouth, where there are always plenty of hands to launch a boat, her weight would cause no difficulty. By means of the raised air-cases placed at the extremes, the absence of side air-cases for a length of 10 feet amidships, the introduction of $2\frac{1}{4}$ tons of water-ballast into her bottom when afloat, and her iron keel, this boat would right herself in the event of being capsized; although, from the form given to her, it is highly improbable that such an accident should occur.

"A passage should be left in the air-cases to approach the stem and stern, for on many occasions the only way in which a life-boat can go near a wreck is end on, when the crew of it must be received either over the stem or the stern. The deep keel, 8 inches, however favourable for sailing, for steadying her in a sea-way, and for aiding her in righting, would be a disadvantage in beaching, and would render the boat more difficult to turn in case of wishing to place her end on to a heavy roller coming in. The area of the delivering-valves is large in proportion to the internal capacity, and would rapidly free the boat of water, down to the level of her draft, which, with her crew on board, would not be to less than to a depth of some inches above the floor. The air-cases are built into the boat, which renders them liable to accidents; if this were remedied, and her internal capacity reduced, a 30 feet or 32 feet boat, built on similar lines, with her internal fittings slightly modified, would make an efficient life-boat, adapted for all uses, and would be an invaluable acquisition.

"This prize-boat recently made a trial trip out to the Goodwin Sands, and proved herself to possess the most extraordinary qualities as a sea-boat. Captain Charlwood, the inspecting commander of the district of the Coast Guard, with Lieutenant Simmons, and Mr. M'Donald the master of the *Rose*, revenue cutter, and a crew of 14 picked men, went out in her to the Goodwin, where she was placed in such positions as to allow the surf to have the greatest effect upon her. Nothing could exceed the admirable style in which she behaved; and enough was seen to satisfy the officers and men who were in her, that she would weather the most tempestuous sea. Her sailing qualities were also tested with the most successful results; indeed, it is said that if it were possible to throw her on her beam ends she would not go over. Such was her buoyancy that, when filled with water, she cleared herself to the grating in about twelve seconds. The success of the boat has been the source of much gratification along the coast."

## APPLEGATH'S VERTICAL PRINTING MACHINE.

Before the introduction of steam, and even for many years after, the largest number of newspaper sheets which could be printed off in one hour, amounted to only one-fourth of the number which were thrown off on the first introduction of self-acting and steam-impelled machinery by the spirited proprietors of the *Times*. This wonderful and important change took place in the year 1814. Previous to that year, the *Times*, like every other newspaper, was printed by hand at the common press, and at the rate of about 300 sheets per hour, printed on one side.

The first patent for printing-machinery was obtained by Nicholson, in 1790, who then proposed placing both the types and the paper upon cylinders, and the use of cylinders also in distributing and applying the ink. By another plan the type was placed upon a table, which was passed under a paper cylinder. In 1813, Donkin and Bacon introduced composition rollers, and suggested the plan of placing the type upon a prism.

In 1814, the first self-acting machine was made by Kœnig, who erected two of them at the *Times* office. This was the first application of steam to printing-machinery, and led the way to all the subsequent improvements, by which so immense a revolution has been effected. Each of Kœnig's machines produced 1,800 impressions per hour, and these continued in operation, at the *Times* office, till 1827, a period of thirteen years.

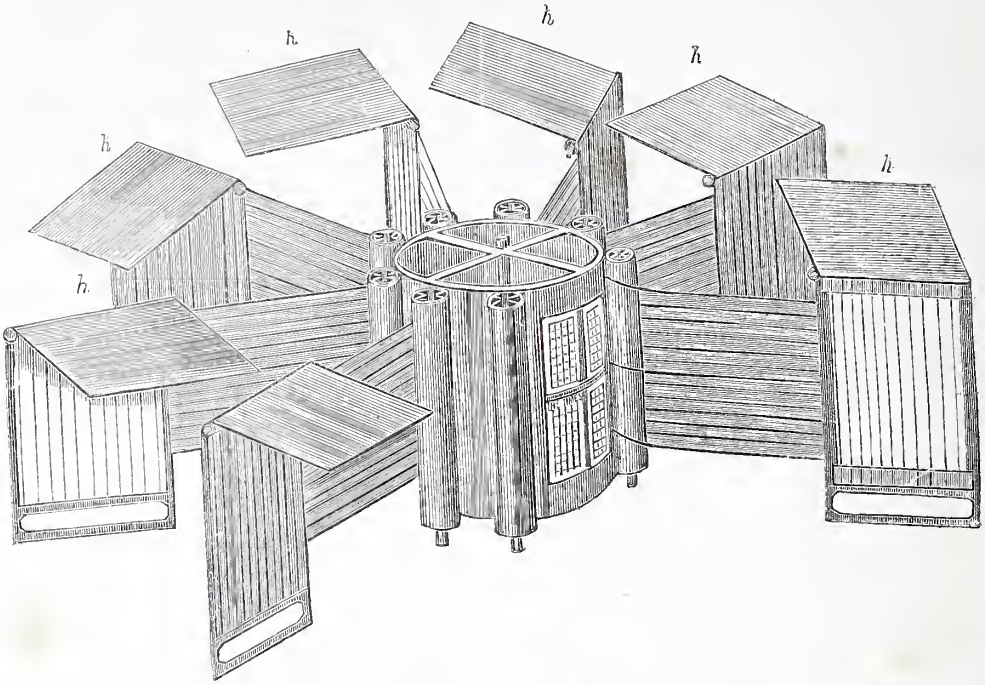
In that interval, however, very considerable improvements continued to be made. In 1818, Cowper (afterwards associated with Applegath) made a machine, in which he introduced the system of inking now generally adopted, and which printed from 2,000 to 2,400 impressions per hour. This is the machine which is now in general use.

The increasing circulation of the *Times*, however, compelled the proprietors of that journal to call for a machine capable of throwing off 4,000 printed sheets per hour, and this problem was accomplished in 1827, by Messrs. Cowper and Applegath conjointly, who effected it by the introduction of four *paper* cylinders, and four sets of inking rollers, instead of one of each such cylinders, as formerly; while one form, as before, containing the type, was made to pass over the various rollers, first in one direction, and then in the other. This machine was adequate to print from 4,000 to 5,000 impressions per hour, and at once superseded Kœnig's machines, which were accordingly taken down. It consists of a table, moved backwards and forwards under four iron cylinders, called the paper cylinders. They are about nine inches diameter, covered with cloth, and the sheets of paper are carried round them between tapes. On one part of the table is fixed the form of type, and over another part are the inking rollers, some of which are placed across, and others in a diagonal position. The latter, as the table moves backwards and forwards, have a motion in the direction of their length, called the "end motion," produced by the motion of the table, and this, combined with the rotatory motion, causes the ink to be more effectually distributed. The reservoir or trough in which the ink is contained is formed of an iron roller, called the ductor, against which the edge of an iron plate rests, and regulates, by its pressure, the quantity of ink given out. From the ductor-roller the ink is conveyed to the table by means of an elastic roller vibrating between them. There are four feeding boards, corresponding to the four paper cylinders, and a "layer-on" is stationed at each, who lays the sheets of paper on the boards, from which they are carried round the cylinders, and thence to the spot where the "takers-off" stand. The sheets are conveyed between three pairs of tapes, which separate, and allow them to fall into the hands of the "takers-off."

Four of these machines are still in use at the *Times* office, and continued about twenty years to meet the increasing circulation of that paper. Latterly, however, they were found to be unavailing in supplying the enormously increased demand, and, instead of 4,000 copies in an hour, Mr. Apple-

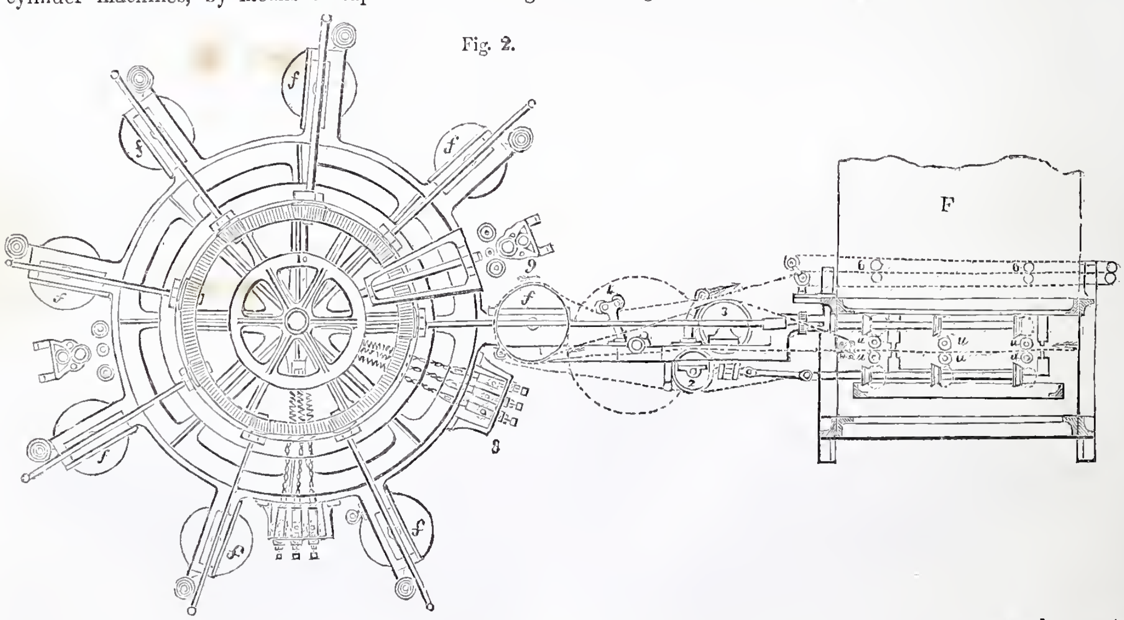
gath was requested to tax his ingenuity in order to produce a machine capable of printing 10,000 sheets within the same time. It would be interesting to know the numerous difficulties which, in all probability, presented themselves, in practically solving this extraordinary problem; suffice it to say, that in May, 1848, this last great improvement was introduced, when Mr. Applegath erected, at the *Times* office, a vertical machine, which produced the enormous number required, namely, 10,000 impressions per hour. Fig. 1 gives a general idea of this machine in perspective, one of the feeders being omitted to show the position of the form. It consists of a vertical cylinder, about 65 inches in diameter,

Fig. 1.



in which the type is fixed, surrounded by eight other cylinders, each about 13 inches in diameter, covered with cloth, and round which the sheets of paper are conveyed, as in the four-cylinder machines, by means of tapes. The inking-rollers are also placed in a vertical position against the large cylinder, and distribute the ink on a part of its surface, the ink being held in a vertical reservoir, formed of a ductor-roller, against which rest two "straight-edges," connected

Fig. 2.



at the back, so as to prevent the ink from running out. The ductor-roller is occasionally pushed against the inking-rollers, to which it thus communicates a steady supply. The paper-cylinders are furnished with a feeding apparatus, *h*, for each, having one boy to lay the sheets on, and another to take them off.

The chief novelty of this machine is the manner in which the type is fixed upon the central cylinder. The type is of

the ordinary kind, and the form is a slab of iron curved on its under side, so as to fit the large cylinder, while its upper surface is formed into facets or flat parts, like the sides of a polygonal prism. These facets or flat sides correspond in width and number to the columns of the newspaper, and between each column there is a strip of steel, with a thin edge to print the rule. This narrow plate of steel is made wedge-shaped in the body to fit the angular space left between the columns of type, and to press the type together sideways, or in the direction of the lines. The type is pressed together in the other direction by means of screws, and is thus firmly held together. It will be observed that the surface of the type, when so fixed in its form, is part of a polygon, and therefore would not press equally upon the paper cylinders if these last were formed exactly cylindrical; each column would receive a weaker impression at the middle than at the sides. To obviate this, strips of paper are pasted round the impression cylinder, in width equal to each column; in the centre of these, narrower strips are pasted, and others narrower still, until the whole surface of the impression cylinder becomes a series of segments of smaller circles, which fit with sufficient exactness to the surface of the type to receive a uniform impression, as the sheets pass round them, over the width of each column.

Substituting the vertical cylinder for the table, the general operation of this machine is similar to that of the four-cylinder machine already described. By referring to figs. 2, 3, 4, in each of which the letters of reference are the same, the details will be readily understood.

The elevation is shown in fig. 4, where *a*, *a*, is the large vertical cylinder or drum, forming the centre of the system, as shown in fig. 1. This drum is mounted on the shaft, *b*, *b*, and is driven by the bevel wheel and pinion, *c*, *d*, the shaft of the pinion, *d*, being supported on the floor, and carried to the prime mover.

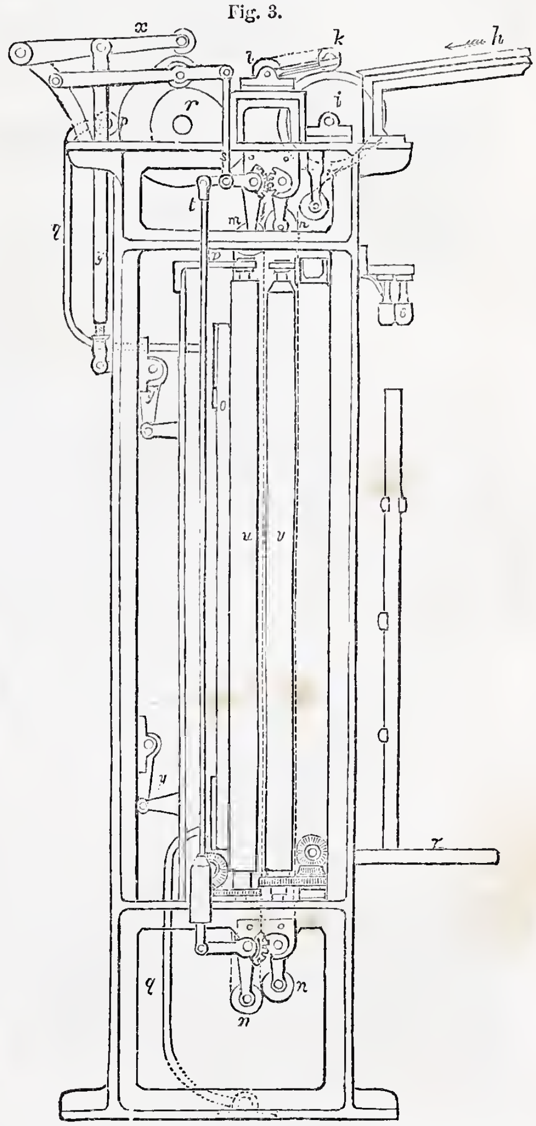
The eight impression cylinders, *f*, *f*, *f*, *f*, *f*, *f*, *f*, *f*, are shown in fig. 2, and two of them appear in the elevation, fig. 4. They are driven by the spur-wheel, *e*, which moves with the axis, *b*, of the drum, *a*, and thus the same speed is secured between the circumference of the drum, bearing the type, and the circumference of each impression cylinder.

The columns of type are fixed in the four type-holders, *g*, *g*, *g*, *g*, and between the columns are the "rules," which, as already mentioned, are narrow slips of steel, wedge-shaped, to fill up the space left at the junction of the columns, like the keystone of an arch. These rules are fitted into the top and bottom of the type-holder, like the blade of a saw in its frame. The central rule is a fixture, in order to avoid the possibility of the type escaping from its place in screwing it up, and each column is jammed up from one end by a set screw. The four pages of type, thus prepared, are bolted to the rings of the central drum.

The impression cylinders, as shown in figs. 1 and 2, are not arranged symmetrically around the central drum. To afford room for inserting and removing the form of type, a greater space is left between one pair than between the others. The sheets are supplied to each of these cylinders from feeding-boards, and each requires a separate apparatus for that purpose. One only is shown in fig. 2.

It will be evident, that the vertical position of the type requires that the paper also should be brought to a vertical position, so as to move laterally round the impression cylinders. This is accomplished in the following manner:—A mass of sheets being piled on the feeding-board, *h*, (fig. 3,) they are pushed forward, one by one, by the "layer-on," over the centre of the feeding-drum, *i*. Two small fluted rollers, *k*, *k*, fixed on what is termed the dropping-bar, are driven by tapes off the roller, *l*. The dropping-bar periodically descends, and the rollers, *k*, *k*, catch the sheet, and advance it between the rollers, *i* and *l*. It is then continued downwards, as shown in the drawing, by tapes passing around the rollers, *m*, *m*, and *n*, *n*. The paper is steadied in the whole of its journey by numerous tapes, which carry the sheet with them in the course indicated, until its progress is arrested by two long narrow strips of wood, *o*, *o*, covered with woollen cloth, and called the "stoppers," one pair of which are advanced forward against the other pair that are fixed. This motion is effected by means of the cam, *p*, which acts upon the arms, *q*, *q*, *q*, *q*, attached to the stopper-frame. At this point the tapes open and leave the sheet in its vertical position, held up by the stoppers. The opening of the tapes is caused by the opening of the rollers, *m*, *m*, and *n*, *n*, and this is effected by the bearings of these rollers being mounted in the ends of levers, which are made to act upon each other by means of the toothed segments shown in fig. 3. The link, *s*, is raised by the cam, *r*, and moves the upper pair of rollers, *m*, *m*, while the motion is conveyed to the lower pair, *n*, *n*, by the connecting rod, *t*. It will be seen that this rod is

Fig. 3.



loaded with a weight at its lower part, the object of which is to keep the friction-roller in contact with the cam, *r*.

In the meantime the stoppers are relaxed, and the paper is seized at the top by two suspending rollers, which are brought together by a cam. These rollers hold the sheet up for an instant, while the three pairs of vertical rollers, *u u*, *u u*, *u u*, (figs. 3 and 4,) are brought into contact to guide the sheet laterally. These vertical rollers, like the impression cylinders, are all driven at the same speed as the printing drum, by means of bevel-wheels and pinions, as already described. By their motion the sheet is advanced into the

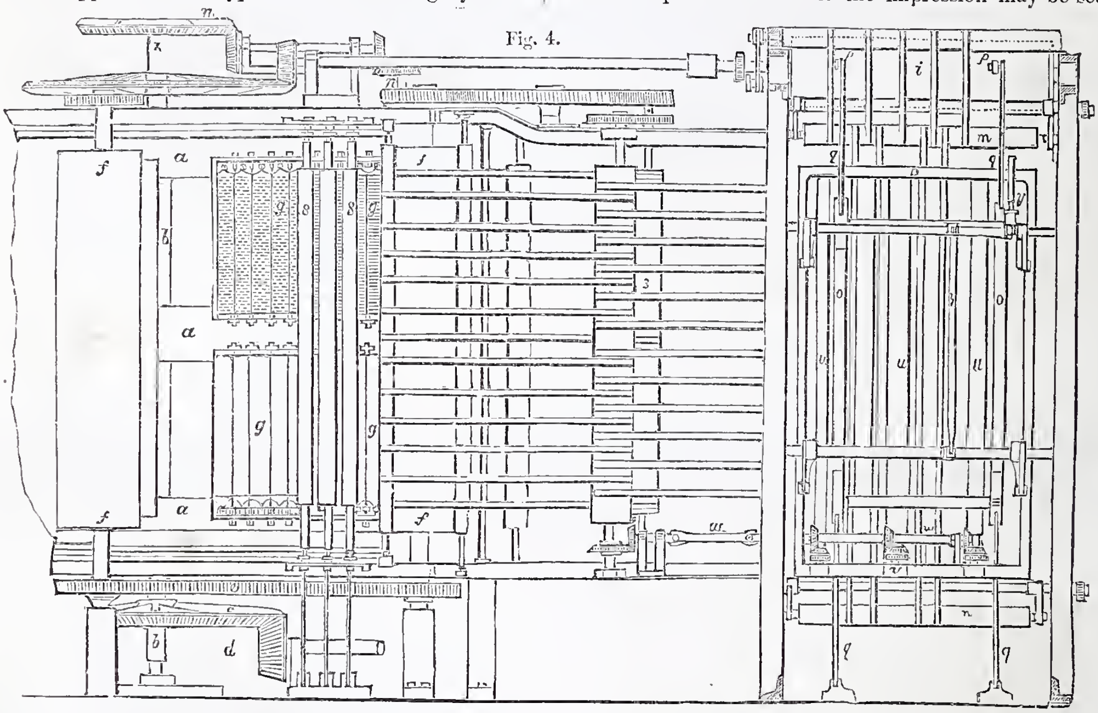
mouth of two sets of horizontal tapes, which pass round the drums, 2 and 3, driven by similar gearing, and carry the sheet onward to the impression cylinder, *f*. In passing round this cylinder it receives the impression, and returns in the direction of the arrows, fig. 2. In its outward passage it meets with another set of endless tapes at the roller 4, which carry it out as far as the roller 5; from this point it completes its course between a single pair of suspending tapes at the top of the sheet, which are pressed lightly together by the pulleys, 6. On arriving at the outer pulley, the tapes are pressed together by a lever and stopped, and the sheet is thus held suspended till drawn down by the attendant, and placed on the taking-off board, F.

A feeding apparatus, such as we have now described, is provided for each of the eight impression cylinders, and the same action takes place at each almost simultaneously, or during one revolution of the central drum, so that for each revolution of the type eight sheets are produced, printed on one side.

It now only remains to explain the apparatus by which the ink is supplied to the type on the revolving cylinder. The ductor-roller, which is shown at 9, fig. 2, forms one side of an ink-box, from which, as the roller revolves by the bevel-gearing, 10 and 11, it withdraws a portion of ink. Over against this is a circular invert or inking-table, to which the ink is communicated from the ductor-roller by two vibrating rollers, alternately in contact with each. The inking-table is placed on the central drum, opposite to the form of type, and three inking-rollers, 8, 8, 8, placed between each two impression cylinders, revolve in contact with it, conveying the ink from the inking-table to the type. The inking-rollers are caused to press outwards against the inking-table by means of coiled springs, as shown in fig. 2; and to hold them inward in contact with the type as it passes, their brass bearings are furnished with set screws. The ink-boxes are kept full by a reservoir placed above them.

Considering the rapidity of action in this machine, the variety of its parts, and the somewhat extended course of the sheet in passing through it, we cannot but wonder that it should perform its office with such remarkable precision. In some copies of the *Times* the impression may be seen a

Fig. 4.



little to one side, and not exactly in the centre of the sheet. It is, however, astonishing, and seems to be little short of a miracle, that it should generally be so true. Both the type and paper move at the rate of about six feet per second, or one inch in the seventieth part of a second, and therefore an error in the arrival of the sheet of paper at the impression cylinder of one-seventieth of a second, would cause an error of one inch in the margin. Yet so accurately is the work performed, that the waste of sheets is said to be considerably less with this machine than with the old horizontal ones still in use.

The whole of the printing at the *Times* office is now performed by four of Applegath and Cowper's four-cylinder machines, and two of Applegath's new vertical machines. If space did not exist for two of the latter, the produce of one might be doubled by having two forms of type on the central drum instead of one, and placing eight other laying-on boards and feeding-drums in a story above the present ones. The following interesting statistics, relative to the printing of the *Times*, may be here appropriately introduced in conclusion:—On the 7th of May, 1850, the *Times* and *Supplement* contained 72 columns, or 17,500 lines, made up of upwards of 1,000,000 pieces of type, of which matter about two-fifths were written, composed, and corrected after seven o'clock in the evening. The *Supplement* was sent to press at 7.50 p.m., the first form of the paper at 4.15 a.m., and the second form at 4.45 a.m.; on this occasion 7,000 papers were published before 6.15 a.m., 21,000 papers before 7.30 a.m., and 34,000 before 8.45 a.m., or in about four hours. The greatest number of copies ever printed in one day was 54,000; and the greatest quantity of printing in one day's publication was on the 1st of March, 1848, when the paper used weighed 7 tons, the weight usually required being $4\frac{1}{2}$ tons; the surface to be printed every night, including the *Supplement*, was 30 acres; the weight of the fount of type in constant use was 7 tons; and 110 compositors and 25 pressmen were constantly employed.

The *Illustrated London News* is now likewise printed by one of Mr. Applegath's vertical machines, which was first erected for the proprietors of that journal in the Crystal Palace, where it was seen in actual operation. In principle, it is precisely the same as those put up by Mr. Applegath in the *Times* office, but of less power, having only four impression cylinders, instead of eight. Each of these impression

cylinders is exactly one-fourth of the diameter of the type cylinder. At each revolution of the latter, four impressions are produced by this machine.

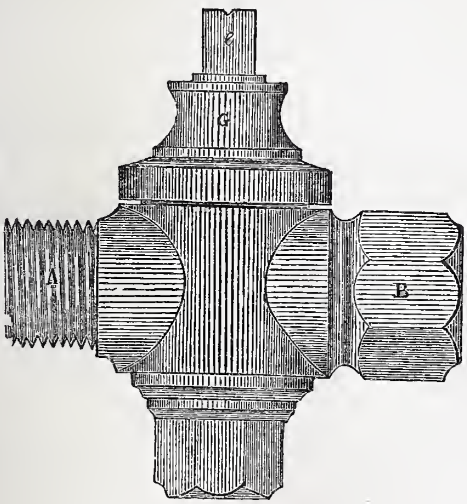
There are several advantages attending the vertical position of the type and paper in these machines: the ink does not sink into the type as it does when it is placed horizontally, and the type is on that account kept much cleaner; the contact of the inking-rollers with the type being regulated, as already described, by long coiled springs connected with the bearings, so that they merely touch the surface of the letters, is another advantage incidental to the vertical position; and a third advantage is, that the dust, or small particles adhering to the paper, are shaken from it when suddenly stopped, and fall to the floor, instead of being deposited upon the form or distributing table, as in the case of horizontal machines.

We may add, that Mr. Applegath is still engaged in making farther improvements in this valuable invention, with a view to adapt it to the uses of the printing business generally.

## IMPROVEMENT IN THE CONSTRUCTION OF STEAM COCKS.

The annexed drawings exhibit an ingenious improvement in the construction of steam cocks, for which we are indebted to Mr. T. G. Cressall, Finsbury Brass Foundry, Wilson Street, London. When the great amount of friction, to which, under ordinary circumstances, the steam cock is liable, is taken into consideration, it will readily be understood that any method, otherwise unobjectionable, by which the friction is reduced, must prove of considerable importance. In the ordinary steam

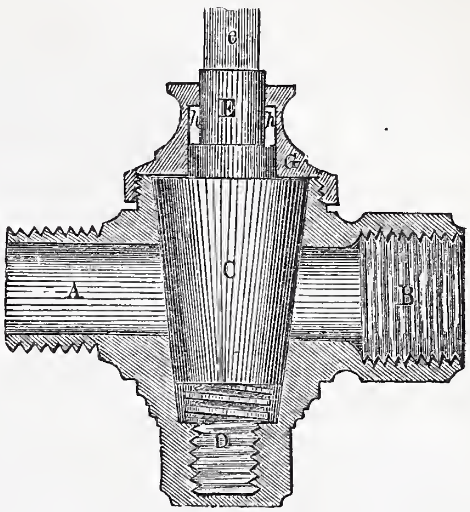
Fig. 1




cock, from the necessarily close contact, and constant friction or grinding of the surfaces of the key and barrel, they soon cut into rings; and farther, the contraction and expansion of the metal, under the alternate influence of heat and cold, renders them speedily unfit for the purpose of securing the steam. These two circumstances, well-known to practical engineers, fully explain the difficulty, not to say the absolute impossibility, of keeping ordinary steam cocks sound for any lengthened period.

The present invention, which is extremely simple in its operation, is intended to obviate these evils, and has been found, under adequate practical test, completely successful. Its principle will be understood by referring to the annexed drawings. Fig. 1 is a side elevation, and fig. 2 the same, shown partly in section. A and B are the screwed ends; C is the plug, terminating at its lower end in a screw, D, and at its upper end in a cylindrical stem, E, and square, *e*; *f* is a helical spring. G is a metal cap screwed on to the body of the cock, and forming a stuffing-box at *h*. On turning the cock a quarter round, to open the passage through it, the screw, D, and spring, *f*, cause the plug, C, to rise clear off its seating, so

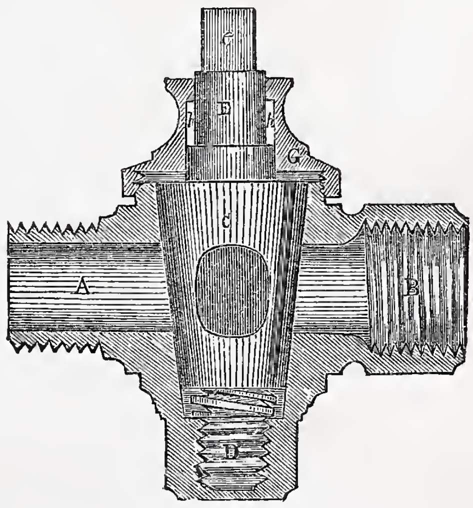
Fig. 2.—*On.*




as to turn without friction or grinding, while escape of steam by the plug, C, is prevented by the packing at *h*.

It will thus be seen that the improvement consists in the configuration and operation of the plug, which, being acted upon by the screw at bottom, is slightly raised in opening the passage through the cock; and again, in shutting off the steam, is returned firmly to its seat. Friction is thus removed, leakage at bottom is rendered impossible, the injurious effect from the contraction and expansion of the metal, if not entirely destroyed, is at least considerably diminished, and the cock is in fact converted into a valve of the simplest description.

Fig. 2.—*Off.*




This improved steam cock, which is equally remarkable for its simplicity and efficiency, has been approved and adopted by some of the most eminent practical engineers in London; and its manifest advantages over the mechanism at present in use, together with its very moderate cost, (exceeding only about 5 per cent. the price of the common cocks,) must speedily ensure its general application.

# NATURAL PHILOSOPHY AND CHEMISTRY.

## CHAPTER XV.

### ON THE PRESENT STATE OF VOLTAIC ELECTRICITY AND ELECTRO-MAGNETISM.

PART I.—VOLTAIC ELECTRICITY.—(*Continued.*)

24. HAVING used the terms, "sensible," and "insensible," in relation to the distances from each other of the molecules of bodies, it may be well to explain more clearly what is meant by sensible and insensible intervals; for much of what we shall have to convey to the reader, in order to enable him to comprehend the true nature of electric and chemical forces, depends upon his correct appreciation of the influence of distance in accounting for the results of molecular action.

25. It is a mistaken notion, however common, that, because a mass of matter appears to our closest natural inspection devoid of pores or intervals between the particles of which it is composed, these particles are in perfect and absolute contact, thus leaving no space or passage for the introduction of any other form of matter, however subtile or attenuated, between them. This is a false conclusion; for the particles of a mass of matter are not in absolute contact, nor is there any one condition of nature in which they can be. Of this, the expansion and compression of bodies afford us abundant proof; and microscopic observation brings the fact home to our comprehension, by disclosing the extraordinary arrangement of the constituents of organic bodies, and displaying spaces innumerable in what—to our unassisted vision—would appear the densest and least permeable mass. But having, by such means, thus far obtained a correct view of the natural constitution of bodies, we are not to content ourselves with the wonders thus opened to our sight, in the belief, that in whatever part of the substance the most powerful microscope fails in detecting a space, there must be true contact between the particles of that substance; for if, in the present limited state of our assisted powers, we are at liberty to lay down any line of demarcation, *here*, we may say, that the boundary between sensible and insensible distances exists; that *here* terminate those—to the naked eye—imperceptible intervals or pores, appropriated to the reception and circulation of perceptible fluids; and *here* commence those intervals, imperceptible even to our best assisted vision, and appropriated solely to the reception of those subtile elements or *primal* forms of matter, equally imperceptible by our artificial, as by our natural powers, and only known to have existence by their wonderful effects upon grosser forms of matter.

26. But notwithstanding the narrowness of such inappreciable intervals, separating the molecules or particles of bodies, we can understand that those intervals may admit of measurement by greater powers than ours, and that there may be as great a difference in the diameters of each space, as the microscope informs us there is in the otherwise invisible pores of the densest wood or most solid ivory. Here, then, in these—to us—immeasurable spaces, in their enlargement or contraction, is to be found the residence of one—if not more than one—extremely subtile element, as well as the cause of the peculiar states which matter assumes, whether solid, liquid, or aëriform, as also of the various degrees of each of these conditions, as exemplified in the nature, diversified properties, &c., of the almost unlimited variety of substances with which we are acquainted.

27. Having thus familiarized the reader to the fact of the really broad distinction between sensible and insensible distances, as well as enabled him to form a notion of the divisibility of the diameter of an inappreciable space, we have placed him in a position to comprehend the mode of action of those hidden powers by which all natural phenomena are influenced and produced, and to reconcile to his mind causes and effects, between which he saw no previous relation.

28. Recurring, now, to the opinions of M. Mossotti upon this subject, so far as they tend to illustrate and support the views previously laid before the reader, we may consider it a fixed principle that, inasmuch as the resistance opposed by bodies to compression increases indefinitely with the reduction of their volume, although their molecules have not come into contact with each other, the force which those bodies exercise is repulsive at the least distances; that at a distance greater than these, but still imperceptible, it must vary with great rapidity, and become attractive, in order that a steady equilibrium of the molecules may be attained; that when it has become perceptible, it must decrease in the inverse ratio of the square of the distance, in order to represent the universal attraction; and finally, that the limits of the distance at which the action changes, vary according to the temperature and nature of the molecules, and determine whether the condition of the body which these molecules compose, be solid, liquid, or gaseous.

29. But while admitting the influence of temperature in regulating the natural condition of bodies, Mossotti does not appear disposed to recognise the existence of caloric as an independent principle, but rather looks upon it and its sensible effects, as the result of peculiar conditions of the electric ether, in which he assumes the molecules of matter to be plunged; for, as the quantity of ether diffused through the immensity of space may be considered as infinite, the atmosphere formed by each molecule for itself is always the same, and its density is only superadded to that which the ether in the same places owes to other causes. This density of the atmosphere of each molecule will be incomparably greater when quite near, or in contact with the molecule, and will decrease very rapidly as its distance from the molecule increases. In this view, if the density of the ether into which the molecules are plunged becomes greater, the density of the atmosphere at any point on the surface of the molecule will increase also; the value of the resistance will consequently become greater, and the molecules will fix themselves in equilibrium at a greater distance. In this result, the ether performs the functions of caloric, and to its greater or less density should be ascribed the temperature and volume of the body.

30. There is certainly much plausibility in the above views; and when we consider that increase or diminution of temperature in a body is always attended by the more or less wide separation of its molecules, and the consequent increase or diminution of its volume; and that change in density of the electric atmosphere is competent to produce similar results, we feel almost disposed to admit the existence of but one subtile principle as sufficient to account for the various conditions as well as properties of matter; but there are reasons (to be hereafter assigned), which, in our mind, must prove a bar to the correctness of this hypothesis, and which require for caloric its recognition as a separate independent principle, antagonistic in its properties and mode of action to the electric ether.

31. Before we quit this part of the subject, in order to prepare the way more effectually for the proper recognition of the principle of but one electric fluid, as well as of the explanations of Voltaic action in accordance with that hypothesis, it will not be amiss to show the reader upon what a rotten foundation the statements in support of the two-fluid theory of Coulomb and Dufay are based. It is broadly asserted, that the hypothesis of two fluids, opposed in their properties, is the only one to be received, because it has been completely confirmed by the results of Poisson's beautiful analysis; but it so happens, that those who have made this assertion, have, either through ignorance or carelessness, omitted the important fact, that although that distinguished mathematician has, for the purpose of establishing his calculations adopted the language of his school, his inferences from them are not more applicable to one hypothesis than to the other. He sets out with the principle, that, "if several bodies, being electric conductors, are placed in presence of each other, and attain a permanent state, the result of the actions of the electric layers which cover them, on a point taken anywhere in

the interior of a body, must, in that state, be null, otherwise, that the combined electricity which exists in the point under consideration, would be decomposed; but that this is contrary to the supposed state of permanence. Now, if for this principle the following be substituted:—" If several bodies, being electric conductors, are placed in the presence of each other, and thus attain a permanent state, the result of the actions of the layers of electric ether which cover them, and of the exterior layers of matter which are not yet neutralized on the electric fluid at a point taken anywhere in the interior of a body, must in that state be null, otherwise the electric fluid which exists in that point would be displaced, which is contrary to the supposed state of permanence." If, therefore, we interpret accordingly the literal denominations employed by M. Poisson in his equations, all his results will be equally true on Franklin's hypothesis. In general, the action of the condensed electric fluid will stand for that of the vitreous fluid of Dufay, and the action exhibited by matter according as it is deprived of a quantity of the electric fluid, will stand for that of the resinous fluid; there is one circumstance, however, which makes a difference between the hypothesis of Coulomb and Dufay, and that of Franklin; namely, that according to the one, the two fluids are moveable in the bodies; while according to the other, the electric fluid is, but the matter is not, moveable; inasmuch, however, as the equilibrium requires that we should only regard the relative position, the mobility of the electric fluid alone is quite sufficient for the establishment of the latter, as a theory fully as explanatory in all respects, and upon much simpler and more natural principles, of the various phenomena which attend electric action.—*(To be continued.)*

# MECHANICS.

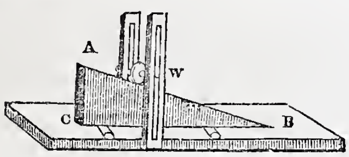
## PART II.—ELEMENTS OF MACHINERY.

### CHAPTER V.

#### THE WEDGE AND THE SCREW.

In our last chapter we described the nature and advantage of the inclined plane, considered as an immovable surface upon which a moveable resistance is to be raised. By exchanging the circumstances; that is, by supposing the resistance to be incapable of motion laterally, but free to move vertically, and supposing also that the weight is raised by the forward motion of the inclined plane, we arrive at the idea of the wedge.

For example, suppose a weight, W, to be so confined by pins passing through slits in two upright bars, that it can move only in a vertical direction, and that it is caused to rest upon an inclined plane A B.



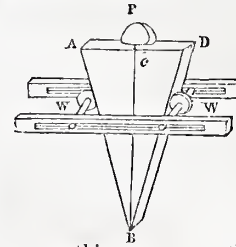

Then, if a force were applied to W, in a direction parallel to B C, and having the same proportion to W that A C has to B C, the weight W would be just supported, and would have no tendency to ascend or descend, as is evident from what has already been said.

But if the plane A B C itself were perfectly free to move, being placed on rollers to remove the friction, such a pressure applied at W would cause the plane to move in the direction B C. Now, if we suppose an equal force applied perpendicularly to the back of the inclined plane A C, the whole system will be kept at rest; and if the force first applied to W is removed, it will be supplied by the pressure upon the pins passing through the upright bars.

If the pressure upon the back of this inclined plane be increased, the plane itself will be pushed forward in the direction C B, and the weight W raised. When a plane is employed in this manner it is called a *wedge*.

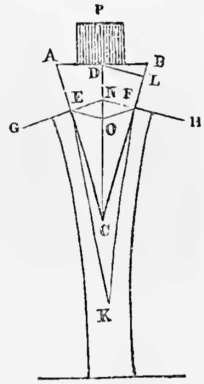
The wedge, of the form shown in the preceding figure, is frequently used, among other purposes, for carrying the steps of upright shafts in machinery, and more particularly for raising the steps, as the shafts wear them,—the power for this purpose being communicated to the vertical face A C.

The wedge has more usually the form of two equally inclined planes, united at the bases, and it is moved in the direction of this common base, which is, indeed, the centre of the wedge. As the object of the first described wedge is more expressly the raising of weights or obstacles, the object of the double-inclined wedge is to separate obstacles. The figure represents the ordinary form of the wedge A B D. It has two equal sides, A B, B D, and may be divided into two inclined planes by the centre line B C. A force P, applied at the back of the wedge, is employed to separate two bodies W, W, which are pressed against the sides of the wedge by a force of any kind. If the direction in which the motion of W, W, must take place, is parallel to A D, this case is exactly like the preceding—the force P, necessary to balance the two forces W, W, being double of that necessary to balance one of them.




Again, when a wedge is employed to split timber, or any other body of that kind, the direction in which the motion of the parts separated would take place must be ascertained, and the relation between the power applied and the pressure produced can then be determined.

In the adjoining figure, A B C represents a wedge composed of two inclined planes, A C D, and B C D. It is in the act of cleaving a block of wood G H I. The main points of contact are at E and F, at which points therefore the resistance acts; and it is easy to see that when the wedge is thrust forward, by whatever means, in the direction D C, it still farther separates from each other the parts E, F, of the block of wood. They must also move in the directions E G, F H, which are perpendicular to the surfaces A C, B C; and in these directions, therefore, the resistance to separation of the parts of the block must act.




For simplicity, we shall consider the action of the forces only on the one side of the centre line D C, knowing that it must be exactly similar on both sides of the wedge. One-half of the power applied, therefore, acts on each side. Now, let D C represent the force acting on the face of the cleft F K; draw D L perpendicular to B C—it must also be parallel to F H—and it will, for this reason, represent the direction of the resistance acting along F H. Let this resistance be indicated by W, and the power by P, then

$$P : W :: DL : DC.$$

But again, if the resistance be in a direction parallel to the top of the wedge A B, then

$$P : W :: BD : DC,$$

that is, the power applied will balance the resistance, when the forces are to each other in the proportion of half the breadth of the wedge to its length.

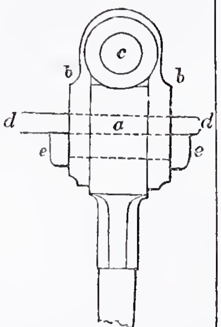
The resistance to the motion of the wedge depends not only upon the angle at its vertex or point, but also on the depth to which it is driven; and further, it depends upon the quantity by which the particles of the mass are displaced; for, being elastic, these particles will tend to come together with a force proportional to their displacement. These are reasons why a wedge is driven with difficulty, when it is driven deep.

However, when wedges are driven into pieces of wood, with the view of splitting them asunder, it is observed that the wood splits up at a considerable distance before the point of the wedge, as shown in the last figure, where the separation

has advanced to K. It follows, that the action of the wedge at the points E, F, is brought to bear upon the cohesion of the body of the wood through the distances E K, F K, which act as arms of levers in further concentrating the action of the power applied. Indeed, after the wedge has once gone over head into the wood, its advantage is not dependent upon the taper it possesses, but upon the length of the split which precedes it. Now this will obviously be in proportion to the breadth of the top of the wedge. At the same time, it is to be remarked that, with an increased breadth of wedge, an increased force is necessary to drive the wedge, in the first place, thoroughly into the piece of wood.

If, in the last figure, G E, and H F be produced to meet at N, and the parallelogram E N F O be completed, then O N will be the resultant of the two pressures E N, F N, showing the tendency of these forces to eject the wedge from the opening. Nevertheless, the friction of the wedge upon the sides of the block is commonly more than sufficient to neutralize this.

The applications of the wedge are very numerous. Nails, awls, needles, axes, saws, &c., all act on the principle of the wedge. This power is also frequently employed in machinery for binding together separate parts of it, as in the familiar example of the butt and strap.




*a* is the butt end of a connecting-rod; *b* the strap which embraces the bush *c*, and binds it to the butt; *d d* a wedge of very small taper, named the cutter, as it passes through slot-holes in the butt and strap; it is driven fast into its place and binds the whole together; *e* is another piece named the gib, so kneed at the ends as to clasp the terminations of the strap, thereby preventing them from spreading. As illustrative of the unlimited power of the wedge, it may be stated, that ships lying in dock are easily lifted up by means of wedges driven under their keels. An engineer who had built a lofty and heavy chimney for a furnace, found, that after some time, owing to the dampness of the foundation, it was beginning to incline. He succeeded in restoring it to its uprightness by driving wedges under one side.

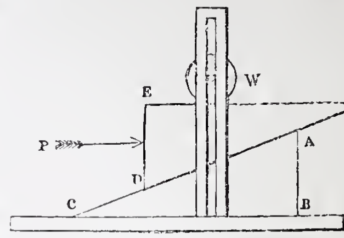
The saw is composed of a series of wedges; and the finest cutting instrument that we have may be regarded as a saw, of which the teeth are very minute, and perhaps less regular. As an illustration of this, the lancet may be pressed against the skin without penetrating, but the instant it is drawn along it starts into the flesh.

The enormous power of the wedge arises principally from its being driven by *impact*. The resistance on its sides, on the contrary, is of the nature of pressure. Now, a pressure, however great, necessarily yields at the *moment of impact* to an impinging force, however small. The momentary separation of the mass thus produced, is rendered permanent by the produced motion of the wedge.

The above statements, therefore, of the advantage of the wedge as a power, are applicable only on the supposition of its being acted upon by simple pressure. The wedge is the only mechanical element that is driven by impact, and its effect, when under the influence of percussive force, is a subject that requires distinct investigation, and which shall be afterwards taken into consideration.

The screw, which is the last mechanical element that is now to be examined, is another modification of the inclined plane, and it may be said to remove the same kind of practical inconveniences incidental to the use of the latter, that the pulley does in reference to the simple lever. The lever is very limited in the extent of its action; so is the inclined plane. But the pulley multiplies the extent of the action of the lever, by presenting in effect, a series of levers acting in regular succession; and just such a purpose is effected by the screw It multiplies the extent of the action of the inclined plane, by presenting in effect a continued series of planes.

Suppose two inclined planes A B C, D E F, of which the former is kept at rest upon its base B C, and the latter is inverted as in the figure, and placed upon the former in such a manner that the planes A C, D F, may be in contact, and the bases, B C and E F, parallel to each other.




Suppose a body W, placed on the surface E F, to be so confined by pins moving in slots in two upright guides, that it can freely move only in a vertical direction; then by applying a sufficient force P to E D, the back of the plane, this plane will slide on the inclined surface A C, and thereby the weight W will be elevated. But this elevation cannot exceed a height equal to the depth E D of the plane. The desideratum, therefore, is to obtain a mode of continuing this elevating process. The most obvious means of accomplishing this is simply to extend the plane D E F, thereby increasing its depth. This method, without modification, would be both clumsy and impracticable to any great extent.

Suppose therefore a triangular plane A B K, fig. 1, the same as the plane A B C, in last figure, formed of some flexible material such as card paper, to be bent round into the form represented in fig. 2, where the base B E F B is circular, and in a horizontal plane, and in which the upper surface of the plane, (fig. 1), assumes the form of a spiral surface A C D B, fig. 2.

*Fig.* 1.

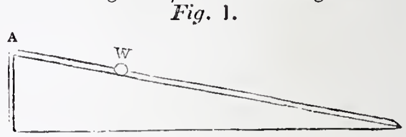
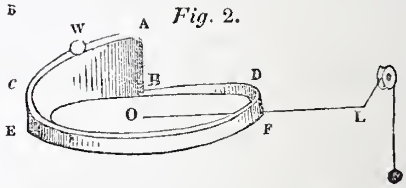



*Fig.* 2.




The alteration of the form of the plane cannot affect the inclination of its upper surface, and thus the same force which would keep a body W at rest upon the plane (fig. 1), would also retain it at rest upon any part of the circular inclined plane, fig. 2.

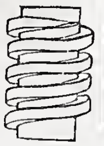
Now let O be the centre of this plane, and suppose an axis to which the plane is connected, passing vertically through this point O; then if the force necessary to keep W at rest on the plane were applied in a direction parallel to the base of the plane, such a force, according to what has already been proved, bears the same proportion to the weight W that A B, the height of the plane, fig. 1, bears to the circumference B E F B. And on the contrary, were the weight W confined by guides so as to move only in a vertical direction, the same force applied to the back of the plane would retain the whole at rest. In fig. 2, the force is applied at A B, in a direction at right angles to the line joining B O, and it is evident that were the force not applied, the plane would by the action of W move backward round its axis.

The effect is the same at whatever point in the circumference that force may be applied. And if, instead of employing a power at F, a point in the circumference F E B, we employ a power P acting perpendicularly at the extremity of a bar O L, and in the plane of B E F, the power necessary to be so employed will be less than that which would suffice at F, in the same proportion that O F is less than O L, or as the whole circumference, B F E, is less than the circumference which the point L would describe in a whole revolution.

Hence the power P is to the weight W in the same proportion as A B is to the circumference which the point L would describe in one revolution.

We may now suppose the circular plane B D C A, extend-

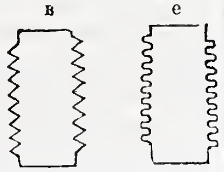
ed indefinitely with the same inclination round the axis passing through the centre O. It will be in fact a series of such planes joined end to end, and forming a regular spiral. It is easy to conceive a cylinder passing up through the spiral, upon which it would lie close at every point; and further, conceiving the cylinder and the spiral to be of one piece, we arrive at the ordinary idea of the *external* screw, as here shown. It consists of a square thread cut upon a cylinder, running continuously round it, and always preserving the same angle with the base.



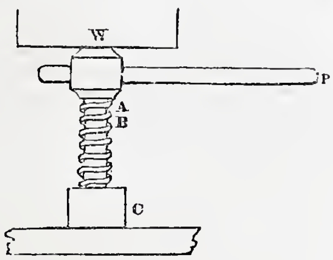
Applying the same idea to the upper plane D E F in the fourth last figure, it ought also to be extended circularly, having the same circumference as the under plane A B C, so that the threads of the spiral formed by it may lie between and upon the threads of that plane. If we also conceive this spiral fitting close *within* a hollow cylindrical space, and forming one piece with the body in which the space is formed, we have a correct idea of an *internal* screw.*

Screws are also constructed with threads, of which the cross section is triangular, and others have circular sections, as at B and C. According as the threads are formed, the screw is termed square-threaded, angular-threaded, or round-threaded.

B C



Whatever be the form of the thread, the longitudinal distance between corresponding points in contiguous threads of a screw is termed the pitch of that screw. For instance, in the annexed sketch of the screw of a screw-press, the distance A B between the same sides of two threads is the pitch; and it is evidently through this height that the weight W is raised during each revolution of the point P to which the power is applied. This height is in fact that of the plane of which the thread A B is formed. Now, in reference to the fourth last figure, it was stated that the power P is to the weight W in the same proportion as A B is to the circumference, which the point L, or P in the above figure, would describe in one revolution. On this principle, therefore, the power of the screw may be calculated.




Suppose, for example, the distance between two threads, A B, of the screw, is one inch, and the circumference which the point P would describe in a whole revolution would be nine feet, or 108 inches—the length from P to the centre of the screw being about three feet—then a pressure of *one* pound at P, would sustain 108 lbs. at W.

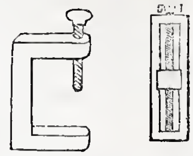
The friction of the parts of a screw is, however, so great, that, in practice, the effect falls far short of the calculated effect.

It is not to be supposed that the screw is solely applied to the raising of weights through considerable heights. The screw is employed to overcome every variety of resistance, and to communicate sustained motion in any direction. For example, in Whitworth's planing machine, the table receives its alternate longitudinal motion from a revolving-screw; and by the same means the slide-rest of his self-acting lathe is moved along its bed.

* The external and internal screws are otherwise known by the appellations of *male* and *female* screws. The coarseness of the analogical derivation of these terms, as well as their being quite unnecessary, ought to expel them from common use.

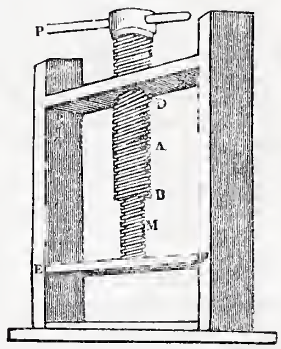
For the purpose of communicating motion to any piece of machinery, the external screw is made of a length necessary to give the required traverse, while the internal screw is generally quite short, embracing half-a-dozen or more threads of the external screw. In this case, the internal screw is termed a nut, and the other is named simply the screw. In their application to machinery, either of them is made stationary in reference to the other, the latter being the one that receives the motion. Thus, in the common screw press, before noticed, the nut C is fixed on the sole of the press, and the screw bears upon it, while rising after the weight W. Again, in the clamp represented at fig. 1, the internal screw is fixed, and the external one moveable; while on the other hand, at fig. 2, which is a sketch of a micrometer screw, it will be noticed that, while the screw is confined by a collar at the neck, the nut slides along the screw between two checks.

1 2



The power in the screw is greater as the inclination of the plane forming its thread is less, and as its radius is less in comparison to the length of the lever at the extremity of which the power is applied. Hence, by lengthening the lever by which the power acts, or by cutting the threads sufficiently fine, the effect of the screw would appear capable of being increased to any extent. It is, however, often practically inconvenient to increase the length of the lever employed; and if the threads of the screw be cut too fine, they become too weak to support the pressure.

To remedy this inconvenience, a contrivance has been invented, somewhat similar to one for a like purpose, described under the "wheel and axle." A screw is cut upon the *outside* of a cylinder A B, and a corresponding *internal* screw is cut in the nut D. The cylinder A B is also hollow, and an internal screw is cut in it, corresponding with an external screw cut upon the cylinder M, which is attached to the sliding part of the press E F.




If the screws upon the cylinders A B and M had just the same pitch, and the upper screw turned by the power P; then as the cylinder M would rise just as much as the cylinder A B would fall, the sliding-board E F would be stationary. But if the pitch of thread on the part M be less than the part A B, then, in each revolution of P, the board E F will be depressed through a space equal to the difference of the pitches of the two screws. It is evident that this difference may be as small as necessary without weakening the screws. And there is an equilibrium when P : W : : as the difference of the pitches of the threads is to the circumference described by P.

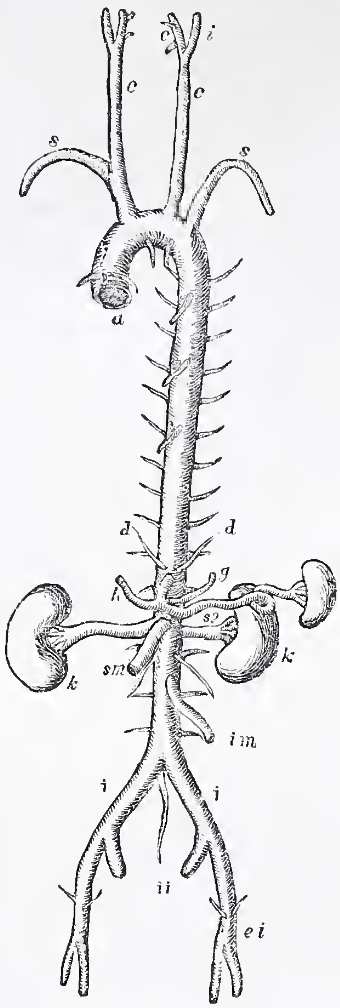
Other applications of the screw are made in machinery in the instance of the worm-wheel, and worm or endless screw, in which the screw by revolving, communicates a greatly reduced motion to the wheel.

## ANATOMY AND PHYSIOLOGY.

### CHAPTER XIV.

THE CIRCULATION.—(*Continued.*)

HAVING examined the central organ of the circulation, let us now turn up the conduits by which it pours out its contents, and those by which it is fed.




The *aorta*, or great artery of the system, has been described as arising from the left ventricle of the heart. It passes first upward, then forms an arch across to the left, and passes down along the left side of the spine through the chest, behind the heart. Just where it has been cut off from the heart, three valves are placed which are seen closed at *a*. Their action in preventing the blood from getting back into the ventricle at the moment when it is dilating, and the aorta contracting by its elasticity, has been already adverted to in chap. xiii., at page 428. In this course, it first gives off two small branches for the nourishment of the heart itself; and then generally gives off three great branches to the head and arms. The first of these is the largest, about the thickness of one's little finger, and divides into the artery of the right arm, and the artery of the right side of the head. The second branch is for the left side of the head, and the third goes to the left arm. The concavity of the arch sends off two or three small branches for the nourishment of the lungs; and the descending aorta gives off from its sides a series of small arteries to run below each rib, and nourish the muscles by which the ribs are connected, and from its front, three or four of like size, to nourish the gullet, which lies just beside them. On arriving in the belly, by passing through the diaphragm, the aorta gives branches to nourish that muscle; and then a very large branch which divides into three, to supply the liver, the stomach, and the spleen, called respectively the *hepatic h*, the *gastric g*, and the *splenic sp*, arteries. Next, a large branch runs down through the belly supplying the intestines, the *superior mesenteric sm*, then a large one on each side to the two kidneys *k*, and lastly, a smaller one to the lower part of the great gut, the *inferior mesenteric im*. Upon the fourth lumbar vertebra, the aorta now divides into its two terminal branches, the *iliacs i*, for the two lower extremities, giving off at the same time an artery not larger than a crow quill, which runs down the middle of the rump-bone, and corresponds to the artery of the tail in beasts.

The artery going to the arm, the *subclavian*, *s*, passes up through the upper orifice of the chest, turns over the first rib, and runs down through the arm-pit. It gives off a large artery to the brain, which runs protected in a curious way through the vertebræ of the neck; and afterwards several branches to the inside of the chest, the root of the neck, and the top of the shoulder. In the arm-pit it gives off branches to the back of the shoulder, and some long ones which run down the side of the chest, supplying, in the female, the breast. The artery of the arm then runs down in a hollow which is seen in the plates illustrating the muscles, between the *biceps* muscle on the forepart of the arm, and the *triceps*, which is seen appearing from behind. We find all the arteries of the limbs running in this way, in hollows between muscles, where they are protected from pressure, and as much as possible out of the way of injury. In this course the artery gives branches which nourish the fleshy part of the arm. In the hollow in front of the elbow-joint, the artery divides into two branches, the *radial* and *ulnar*, running down the fore-arm on their respective sides. The ulnar, besides, gives off a considerable branch which runs down in the middle, for the supply of the deep muscles. It is the radial artery in which it is the practice to feel the pulse, not on account of anything peculiar in the artery, but because it is most conveniently got at. The Chinese have an idea that every different pulse in the body has a different meaning, giving warning of the affection of some particular organ. After what has been said already, it need scarcely be remarked that this is a fallacy, because the pulse must be the same in every artery, as in all it is produced by the stroke of the heart; and all that we can learn from it, is the state of the circulation, whether quick or slow, hurried or languid, regular or irregular, with some minute shades of difference, which, however, give valuable information to the practised finger.

On reaching the hand, the ulna is seen passing in front of the wrist; and, arching to the space between the thumb and forefinger, gives off from the convexity of this arch four *digital* branches. One of these belongs to the inner side of the little finger, and each of the others goes to the division between the fingers, and sends branches along the opposite edges of each, the artery of the one edge communicating freely at the point with the artery of the other edge. The radial artery at the wrist gives off a small superficial branch, which supplies the ball of the thumb, and often communicates with the superficial arch. It then passes out of sight, winding round the root of the thumb, going between the thumb and forefinger, supplying the thumb, the outer side of the forefinger, the deep part of the palm, and communicating with the termination of the palmar arch. These are the arteries which are apt to suffer from knives being stuck into the hand, and though not very large, they bleed very profusely. The radial and ulnar arteries, near the wrist, where they lie superficial, not unfrequently suffer from such an accident as a servant's breaking a pane of glass while cleaning the window; they cannot be stopped by bandages, and must be secured by a surgeon, with a ligature.

The *carotid* artery *c* runs up the side of the neck more than a quarter of an inch in diameter, and just below the angle of the jaw divides into two nearly equal branches, the one going into the inside of the head to supply the brain *i*, and the other being distributed over the outside of the head and face *e*. One branch runs down the forepart of the neck; a second goes into the tongue; a third runs up the face, and encircles half the mouth, meeting with similar branches from the opposite side, which complete the circle in the lips, where it may be felt beating on the inside, by catching the lip between the finger and the thumb. A fourth branch passes to the back of the neck; a fifth to the back of the head; and a sixth to the outer ear. The terminating branches are, one to the throat; one to the deep parts of the face; and one to the temples, where it is felt beating. This last is the only artery which it is permitted to open for the purpose of drawing blood; because it can easily be stopped, by compressing it against the bone on which it lies. It is opened chiefly for affections of the head, as in apoplexy, or in fever. A gentleman, formerly well known in Glasgow, was seized with a fit of apoplexy while standing at a window, against which he fell; the glass cut the temporal artery, and so much blood was lost from it before the surgeon arrived, as to have brought him round.

The *aorta*, it has already been said, bifurcates into the arteries for the lower extremities, called the *iliacs* from the Latin name *ilium*, for the haunch-bone. Each of these again divides into two branches, one of which, *i i*, supplies the parts within the pelvis, and terminates on the buttock, and the other *e i*, passes out over the brim of the pelvis in front, and runs down the thigh, under the name of the *femoral* artery. (Latin, *femur*, the thigh.) The femoral artery gives branches to the great muscles about the hip-joint, and to those on the thigh itself, and then twines round the inside of the thigh to its backpart, where it enters the ham. In the ham, which, it has already been stated, signifies anatomically the hollow behind the knee, it gives off five small branches to nourish the knee-joint, and then divides into the three arteries of the leg. One of these perforates between the bones of the leg to the front, where it runs down, supplying the muscles in this situation, and terminating on the back of the foot; another runs on the outer side of the back of the leg, close to the *fibula;* and the third, which is the principal one, runs down to behind the inner ankle, where it may be felt beating, turns into the sole, and is distributed to the parts there in a manner similar to the palmar arch in the hand, communicating between the first and second toes with the artery on the back of the foot. This artery is liable to be wounded when it lies behind the ankle, as with a scythe, or the blow of an adze slipping from a piece of wood; and the author once saw it cut in a boy, by a sharp stone which another had thrown at him. When wounded, it requires to be exposed and tied like those at the wrist.

The arteries consist of three coats, or layers; an internal one, which is very smooth and thin; a middle one, which is highly elastic, and on which their action principally depends; and an external one, which connects them with the neighbouring parts.

The extreme arteries, or ultimate branches, into which they divide, are said to terminate in four different ways. Many of them terminate in minute pores in the intimate substance of the different parts, to allow the blood to exude, for the purpose of nutrition. Some of them terminate in secreting organs, furnishing blood to be converted into saliva, bile, urine, and so on. Others terminate on exhalant surfaces; that is to say, on the surfaces which are constantly kept moist, such as the membranes of the lungs, and of the belly. Lastly, the remainder, and by far the greatest number, terminate in the commencement of the veins, (as represented in the diagrams in last article) sending back by them the blood which has not been expended in these three ways.

In describing the veins, we must proceed in the opposite direction from that which we have followed in describing the arteries; commencing at the branches, and proceeding along the trunks to the heart. They are much more numerous, and of greater capacity than the arteries, so that the blood moves in them much more slowly. They do not pulsate like the arteries; for the impulse of the heart is nearly lost upon them; and hence, when opened, the blood does not flow from them in jets, but in an equable stream. They consist of two coats, an outer, which is very distensible, so that the vein can swell very much, and an internal one, which is smooth, and in many respects similar to the lining membrane of the arteries. There is one striking difference between them and the arteries, that they have valves placed at distances of an inch or two, which prevent the blood from flowing backward from the heart towards the extremities. Hence is the use of tying a fillet round the arm previous to bleeding; the blood is constantly arriving from below, because the pressure is not great enough to obstruct the arteries; but it cannot get up past the bandage; the veins are therefore distended, and become prominent, so as easily to be seen and punctured; and then, as the blood cannot get down the arm again for the valves, it is necessitated to jet out at the orifice. The veins in the limbs lie in two sets, a deep-seated, and a superficial. The deep set lie alongside of the arteries, there being generally two to each artery: the superficial lie immediately under the skin, and above the fascia or sheath of the limb, and these two sets have every here and there branches communicating between them. Hence, when pressure is made by the muscles on the deep set, the blood escapes into the superficial, and finds by that road a passage to the heart. The reasons why bleeding is done in the veins are twofold,—first, that they are more easy of access than the arteries,—and second, that they heal readily, by the mere application of a bandage.

On the back of the hand, the veins lie above the extensor tendons, escaping the pressure to which they would have been subjected in the palm. They then take their course up the front of the fore-arm, and over the elbow, where one of the largest runs directly over the artery. In former days, when the lancet was used by the farrier and the midwife, the artery was not unfrequently wounded here, through the vein; and serious consequences were the result. This accident is seldom seen now, when medical practitioners are spread all over the country. Above the elbow most of the veins dip deep to accompany the artery, and in the arm-pit the vein is nearly the size of one's thumb. Passing up under the collar-bone, it meets the deep jugular vein at the root of the neck. These two there form a large vein, which meets a similar one of the opposite side, and these, again uniting, form the descending great vein, which pours the blood from the head and upper extremities, into the right auricle of the heart.

On the head a number of veins collect from the scalp, and form a vein in front of the ear,—the temporal vein. Below the angle of the jaw, this receives the vein from the face, and then the one from the tongue, and forms the external jugular vein, in which we are accustomed to bleed in cases of apoplexy. It passes down the side of the neck to the collar-bone, and joins the great vein of the upper extremity. The blood which has been circulating in the brain comes out of the cranium by two large holes, one on each side, and forms the deep jugular veins. These receive the branches from the deep part of the face, and form a vein as thick as one's thumb,—the deep jugular, which lies close to the carotid artery.

The blood of the lower extremities is collected by veins placed on the back of the foot, that they may escape pressure; and from these one large vein passes up the inside of the leg, and another along its back, with a multitude of smaller branches which keep up a communication between them. Besides, there are, of course, two deep-seated veins to each of the three arteries of the leg, all of which unite in the ham to form the great vein of the limb, lying close upon the main artery. The vein on the back of the leg here joins this vein. The deep vein then continues up alongside of the femoral artery, till in the groin it passes over the share-bone, and enters the belly. The superficial vein on the inside of the leg joins it three or four inches before it enters. The two great veins of the two lower limbs now pass up to meet one another, beside where the aorta bifurcates, receive the blood from about the pelvis, and form the inferior great vein. This vein, about an inch in diameter, now passes up through the belly on the right side of the spine, and receives the veins from the kidneys, and some other small ones. Just before passing through the diaphragm, where, in a large man, it will be nearly two inches in diameter, it receives four or five large veins from the liver. The blood from the stomach, spleen, and intestines, takes a curious course. These veins meet and form a large vein which goes to the liver, where, instead of joining the great vein at once, it divides like an artery, ramifies through the liver, and then returns its blood by the four or five large veins mentioned a few lines back.

In the "Botanic Garden," that curiously imagined, and quaintly expressed poem, by Dr Darwin, there is a very pretty description of the circulation, which it may be permitted to quote:—

"So from the heart the sanguine stream distils,
O'er Beauty's radiant skin in vermil rills;
Feeds each fine nerve, each slender hair pervades,
The skin's bright snow with living purple shades,
Each dimpling cheek with warmer blushes dyes,
Laughs on the lips, and lightens in the eyes.

Erewhile absorbed, the vagrant globules swim.
From each fair feature, and proportioned limb,
Joined in one trunk, with deeper tint return
To the warm concave of the vital urn."

The principal diseases incident to veins are their becoming varicose, and their inflaming. The veins of the lower limbs, in persons who have much standing, become distended by the pressure of the long column of blood above them, so that the valves are forced; and the pressing column thus becomes longer—and of course always the longer the worse—because the pressure is so much the greater. The blood does not now get freely back from the legs; the smaller veins become swelled and twisted, having the appearance of knots of blue cords immediately underneath the skin. Sometimes the feet become swollen and almost dropsical; sometimes the skin gives way, and bleeding ulcers form, which are exceedingly difficult to heal. To obviate these evils, the legs must be kept constantly bandaged, or elastic stockings worn, such as are to be got at the instrument-makers, to compress the limbs, and so prevent their veins from being over-distended. The inflammation of the veins occurs after their being injured, either by accident in the limbs, or by the tearing they undergo, in the womb, in the process of child-bearing. The lining membrane of the veins, when inflamed, suppurates, and pours out purulent matter, which is conveyed along with the blood through the rest of the system, producing the most disastrous effects, from which scarcely one recovers.

The forces by which the blood circulates through the veins, are generally considered to be three. The propelling power of the heart probably still exerts some influence on the blood in the minute arteries, in order to drive it into the small veins; the right side of the heart seems to exercise a suction upon the great veins which terminate in it, or at least the action of inspiration does so; and the compression of the muscles causes the blood to move towards the heart, as the valves prevent it from retreating towards the extremities. This is the reason why, in bleeding, something is generally given to the patient to turn in his hand, that the muscles of the fore-arm may be called into play, and at every motion, the stream is seen to spout with accelerated force.

When an artery is wounded, it does not heal again as a vein does; but the skin over it may heal, and then the blood is forced into the cellular tissue, forming a bag full of blood, which pulsates with great force, and is called an *aneurism*. For the cure of this disease it is necessary to expose the artery and tie it with a thread; its sides then grow together, and the aneurism becomes obliterated, while the blood gradually finds its way through the small branches which communicate from the upper to the lower part of the limb, and become enlarged, so as to convey a supply adequate for its wants. This is one of the most successful applications of scientific surgery. Sometimes the coats of the artery dilate, and form an aneurism, without any previous wound. They are besides liable to inflammation and to ossification.

The frequency of the pulsations of the heart varies much in different individuals, but generally according to a regular gradation at different ages, becoming slower from infancy up to old age. The pulse of an infant in the womb ranges from 140 to 180 in the minute, as can be ascertained by listening with the stethoscope: after birth it diminishes in frequency, but is still above 100; in persons of adult age, from 70 to 75 is the usual average, and in men come as far as sixty, the pulse usually beats seconds. The pulse in females is quicker than in males. It varies, besides, according to various modifying causes. Exercise quickens it, rest calms it; even on sitting up, it will be found four or five beats quicker than while lying down. In some few, it may be felt beating not more than 40 in the minute. The whole quantity of blood in the body of a full-grown man, is calculated at 35 lbs. of 12 oz., so that if the heart beats 75 times in a minute, and expels two ounces from each ventricle at each beat, the whole blood will pass through the circulation in two minutes and a-half.

# THEORY AND PRACTICE OF DYEING.

## CHAPTER III.

ON THE MANUFACTURE OF INDIGO—INDIGO OF COMMERCE—MODES OF ASCERTAINING ITS RELATIVE VALUES—CHEMICAL PROPERTIES—ACTION OF NITRIC ACID, CHLORINE, &C., UPON INDIGO.

In the preceding article, we mentioned that, besides the green of leaves and the colours of flowers, which we considered common to all vegetables, there were other colouring matters, which existed only in certain kinds of vegetables, and in particular parts of the vegetable. Indigo is one of these: it belongs to a genus of leguminous plants found in India, Africa, and America, named *Indigofera*. Botanists have described about sixty species of this genus. These all yield indigo; but the species from which it is usually extracted are the *I. anil*, the *I. argentea*, and the *I. tinctoria*. It is also extracted from a tree very common in Hindostan, (the *Nerium tinctorium* of botanists,) and from the woad plant, (*Isatis tinctoria*,) which is a native of Great Britain, and of other parts of Europe. The colouring matter of these plants resides wholly in the cellular tissue of the leaves, as a secretion or juice—not, however, in the blue state in which we are accustomed to see indigo, but as a white substance, which, as we shall presently see, remains white, so long as the tissue of the leaf remains perfect. When this tissue is by any means destroyed, the indigo absorbs oxygen from the atmosphere, and becomes blue.

Of the early history of indigo little is known; neither is it known when it was first used as a dye-stuff. The Greeks and Romans used it as a paint, under the name of *Indicum*. Its value, as a dye-stuff, was not known in Europe, till nearly the close of the sixteenth century, when it was imported from India by the Dutch; but our legislators, for a long time, prohibited its use in England under severe penalties. These prohibitions continued in force till the reign of Charles II., and the reason consisted in its being considered a corrosive substance, and capable of destroying the fibres of cloth, and therefore calculated to injure the character of the dyers of this country. This opinion, no doubt, sprung from the strong and interested opposition given to its use by the cultivators of the woad, which was then regarded as an important branch of national industry.

The following passage, from "Barlow's Manufactures and Machinery of Great Britain," affords a striking illustration of the political economy of the age, and of the narrow and mistaken ideas which generally prevailed throughout Europe, even down to a comparatively late era. Woad was a native production, and we need not say that all who were interested in its cultivation were zealous protectionists even in those days:—

"When indigo was first introduced, only a small quantity was added to the woad, by which the latter was much improved; more was afterwards gradually used, and, at last, the quantity became so large, that the small admixture of woad served only to revive the fermentation of the indigo. Germany thus lost a production by which farmers, merchants, carriers, and others, acquired great riches. In consequence of the sales of woad being so much injured, a prohibition was issued against the use of indigo by Saxony, in the year 1650. In the year 1652, duke Ernest the Pious caused a proposal to be made to the diet by his envoy, that indigo should be entirely banished from the empire, and that an exclusive privilege should be granted to those who died with woad. This was followed by an imperial prohibition of indigo on the 21st of April, 1654, which was enforced with the greatest severity in his dominions. The same was done in France; but, in the well-known edict of 1669, in which Colbert separated the fine from the common dyers, it was stated, that indigo should be used without woad; and in 1737 dyers were left at liberty to use indigo alone, or to employ a mixture of indigo and woad."

The plant which yields the indigo in Bengal is a small straight plant, furnished with thin branches, which spreads out and forms a sort of tuft; the average height is four feet, but on good ground it sometimes attains a height of even seven feet. The leaves are soft, and somewhat like those of the common clover, and the blossoms are of a light reddish colour. The plant is at its greatest perfection when in full blossom, and yields the greatest quantity of indigo.

There are two methods for extracting the colouring matter from the leaves: the first is by fermentation and beating. This process is conducted in two large brick cisterns or vats, built in

relation to one another, like two steps of a stair. The upper one is termed the steeper, because in it the fermentation is conducted. At the bottom of this cistern there is a plug-hole entering into the other, through which, when the process of fermentation is finished, the fluid is run off into the lower cistern, denominated the beater, because in it the process of beating the fluid by paddles, to separate the feculæ from the water, is performed. The plant, when cut, is tied up in bundles about five feet in circumference, and conveyed as quickly as possible to the vat; for, were it kept but a short time in heaps, the indigo in the plant would be destroyed. The upper vat is filled to about five or six inches from the top with these bundles laid in regular tiers. To prevent the throwing up of the herb by the swelling and agitation caused by the fermentation, there are irons built in the two side walls, opposite to one another, to which are fastened beams of wood, which traverse the whole length and breadth of the vats. When the vat is sufficiently filled with the vegetable, a strong grating of bamboo, large enough to cover the whole surface, is laid over the plant, and fastened down by the cross beams. These precautions being completed, cold water is poured as quickly as possible into the vat, till the surface rises within three or four inches of the upper edges. In a short time fermentation commences, and is completed in from nine to twelve hours. Towards the end, the action is very brisk, swelling and throwing up frothy bubbles, which sometimes rise like pyramids. These bubbles are white at first, but after a little exposure to the air, they become blue, and then purple. This part of the operation requires great skill. If the fermentation be too long, the indigo will be much damaged; and, if too short, the quantity is much diminished. When the liquor ceases to swell, it is let out into the second or beating vat, and is then of a light green colour.

The liquor being now into the lower or beating vat, a number of men enter it, furnished with oar-shaped paddles, about four feet in length; they continue to walk backwards and forwards, agitating or beating the liquor with these paddles. At the commencement of this agitation the liquor begins to froth; but this is prevented, provided the fermentation has not gone on too long, by a few drops of oil. In the course of an hour and a half, the liquor begins to granulate, and assume the appearance of agitated water, full of wood grounds. This part of the process also requires considerable care and management; for, if the beating be stopped too soon, the indigo will not be all separated from the liquor, occasioning considerable loss; if continued too long, the granulated particles are broken, and dispersed through the liquor, and do not readily fall to the bottom. When the beating is completed, the vat is allowed to settle; the grains which constitute the indigo fall to the bottom, and the supernatant liquor is let off by plug-holes in the side of the vat. The precipitate is then removed to a copper boiler, to which there is a fire kept till the liquor becomes as thick as oil. Some manufacturers bring it to this state by causing the liquor to boil; others by keeping it at a moderate temperature. The former process produces lighter indigo than the latter. In this state it is put into a large flat vessel, furnished at tho one end with a cloth filter. After the most of the liquor has filtered through, the indigo remains in the vessel about the consistence of butter. It is then put on proper frames, and subjected to considerable pressure by a sort of screw press; and is now ready to be cut into small cakes, which are placed upon boards in a drying-stove; when dry, these cakes are packed up, and in this state form the indigo of commerce.

The other method of extracting the indigo from the plant differs from that described, only in the first operations. Instead of putting the plant into the vat when newly cut, it is spread out to dry in the sun for two days, and then thrashed to separate the leaves from the stems. The leaves are then kept until they have changed from a green to a bluish-gray, or lavender colour; they are then put into the first vat with warm water, and kept stirring, till the leaves are so completely wetted as to sink. The liquor is then instantly let off into the beating-vat, where it is treated as already described.

The chemical changes which take place during these operations are not well understood, and the various opinions expressed by chemists concerning them are not very easily reconciled. Berthollet in his Elements of Dyeing, while describing the process of the first or fermenting-vat, says, "In the first a fermentation is excited, in which the action of the atmospheric air does not intervene, since an inflammable gas is evolved. There probably results from it some change in the composition of the colouring particles themselves, but especially the separation or destruction of a yellowish substance, which gave to the indigo a greenish tint, and rendered it susceptible of suffering the chemical action of other substances. This species of fermentation passes into a destructive putrefaction, because the indigo, as we shall see, has a composition analogous to that of animal substances."

Dr Ure, in his Dictionary of the Arts and Manufactures, says, that from some experiments made upon the gases given off during fermentation, they were found to be composed, when taken about the middle of the operation, of 27·5 of carbonic acid gas, 5·8 of oxygen, and 66·7 of nitrogen, in the 100 parts; and towards the end of the operation, they consisted of 40·5 of carbonic acid gas, 4·5 of oxygen, and 55 of nitrogen. No carburetted hydrogen is disengaged. "The fermenting leaves," using the Doctor's words, "apparently convert the oxygen of the air into carbonic acid, and leave its nitrogen free." They also evolve a quantity of carbonic acid spontaneously. It will be observed that these two opinions are decidedly contradictory; the one says that the action of the atmosphere does not intervene, and that an inflammable gas is evolved; the other, that there is no inflammable gas evolved, and that the air is apparently the principal agent in effecting the various changes. But when we recollect that the leaves are all under the liquor, and kept so by the fixed position of the beams, there can be little contact between the fermenting leaves and the air; hence the conversion of its oxygen into carbonic acid gas must be very limited.

Dr Kane says of this process:—"After some time a kind of mucous fermentation sets in; carbonic acid, ammonia, and hydrogen gases are evolved, and a yellow liquor is obtained, which holds the indigo dissolved. The theory of this action is, that by the putrefaction of the vegeto-animal matter of the leaves, the indigo is kept in the same white soluble condition in which it exists in the plant."

Dr Thomson, in his Vegetable Chemistry, supposes that the indigo exists in the plant in union with another substance, and during fermentation that substance is decomposed, and carbonic acid gas consequently evolved. But we will give his own words. "The leaves of the indigofera yield a green infusion to hot water, and a green powder may be precipitated from it; but unless a fermentation has taken place, neither the colour nor the properties have any resemblance to those of indigo. There is little doubt that in the leaves it exists in the state of *white* or *deoxygenated indigo*, and that during the fermentation, it combines with the requisite quantity of oxygen to convert it into *blue indigo*. The evolution of carbonic acid gas, renders it not unlikely, that the *white indigo* was in combination with some principle (probably of an alkaline nature) which was decomposed during the fermentation."

These discrepancies of opinion, relative to the nature of the changes which take place during fermentation, show that proper investigations have not yet been made into this part of the process; and it is obvious that until this be done, any hypothesis founded upon statements concerning the gases evolved, must be unsatisfactory. The supposition hazarded by Dr Thomson certainly appears to us the most consistent; for, as deoxidized indigo combines readily with alkaline substances, and as the vegetable alkalies almost always contain nitrogen, we can easily conceive of that gas being evolved either free or in combination with hydrogen, forming ammonia. It may yet be found that indigo, like gallic acid (noticed in last chapter), does not exist in the living vegetable, but is the result of a decomposition of some more complicated compound.

The chemical action which takes place in the second vat in which the beating process is conducted, is apparently much more easily explained, and therefore the discrepancies among writers on the subject, are not so great. We shall give only two quotations. Berthollet says, "Hitherto the colouring particles have preserved their liquidity. In the second operation the action of the air is brought into play, which, by combining with the colouring particles, deprives them of their solubility, and gives them the blue colour. The beating serves at the same time to dissipate the carbonic acid formed in the first operation, whose action is an obstacle to the combination of the oxygen." Dr Ure's opinion is thus expressed:—"The object of the beating is threefold; first it tends to disengage a great quantity o carbonic acid present in the fermented liquor; secondly, to give

the newly developed indigo its requisite dose of oxygen by the most extensive exposure of its particles to the atmosphere; and thirdly, to agglomerate the indigo in distinct flocks or granulations. In order to hasten the precipitation, lime water is occasionally added to the fermented liquor in the progress of beating; but it is not indispensable, and has been supposed to be capable of deteriorating the indigo."

That the liquor in the beating vat absorbs oxygen from the air, as the indigo separates from it, has, we believe, been ascertained by direct experiment; and it is also known to manufacturers, that sunshine assists in the separation of the indigo from the liquor. But, though these facts may have been ascertained, it does not give us any positive information respecting the nature of the change which takes place in the vat; neither can we expect such information till it be ascertained what keeps the indigo in solution previous to the operation of beating. Both oxygenized and deoxygenized indigo are insoluble in water; there must therefore be some substance in the liquor capable of holding the indigo in solution previous to being beat. According to our present knowledge of the nature of white or deoxidized indigo, there is no other substance can hold it in solution except the alkalis and alkaline earths. But during such a generation and emission of carbonic acid gas, the existence of any alkali capable of holding the indigo in solution in those vats is next to impossible, and the results prove the contrary; for while the acid is liberated, the indigo becomes more insoluble—a result which is just the opposite of what we conceive would take place were an alkali present; except we suppose that the carbonic acid is the result of the decomposition of the alkali, or is evolved as already hinted, from the decomposition of a substance which is resolving itself into indigo.

Having given the opinions of several chemists upon the chemical nature of the manufacture of indigo, and hinted at the difficulties which some of these theories involve, we shall now consider the nature of indigo; and, whatever be the chemical changes which take place in the beating operation, we are certain that the indigo is precipitated in union with various other substances, rendering it very impure. The best indigo of commerce, according to several analyses, contains only 75 per cent. of pure indigo, while some of the inferior kinds do not contain above 20 or 30 per cent. Part of these impurities may be dissolved in water, by alcohol, by dilute acids, and by alkaline leys. Berzelius found these impurities to consist, besides a little iron, clay, lime, magnesia and silica, of a substance resembling vegetable gluten,* which may be obtained by digesting indigo in dilute sulphuric acid (vitriol); also a *brown matter* which he terms indigo brown, and which he obtained by digesting the indigo in strong potash ley after the gluten was extracted. He found likewise a red resinous substance, which he termed indigo red, and was obtained by boiling the indigo in alcohol, after digestion in the acid and alkali. Several experiments have been made upon the colouring properties of these substances, but the results have shown that they are incapable of being used as a dye. On the contrary, as we shall afterwards have occasion to remark, some of them being more soluble than the pure indigo, and much more easily decomposed, their presence is very hurtful in some cases where particular attention is not paid to those properties, especially when the indigo is to be used as sulphate of indigo.

From the great difference in the quality of indigo, it would be of the utmost importance to the dyer to have an easy method of ascertaining its true value. This, so far as we are aware, has not yet been obtained; the various methods proposed generally imply formal analyses, which, however important they may be to the dyer, are too delicate and tedious to be generally adopted. The method universally practised in the dyehouse is, comparison—putting several samples together, breaking and comparing their clean surfaces. The best indigo generally is of the deepest violet blue, and the finest grain, if scratched by the nail, presents a copper hue; but notwithstanding great care and long practice in thus judging of the value of indigo, it often happens that the lot chosen turns out to be of inferior quality, and is not known until it is in the vats, and its price marked against the dyer.

* Gluten is the substance which gives wheat flour, starch, &c., the property of paste. It is a distinct vegetable substance composed of oxygen, hydrogen, nitrogen, and carbon, and it is the most nutritive of all vegetable compounds.

The process of Berzelius, just alluded to, is to take a weighed quantity of the indigo of commerce in very fine powder, and digesting it in dilute sulphuric acid, next filter and wash it; then digest what remains on the filter in strong potash or ammonia; filter and wash again; then boil the remainder in strong alcohol; what remains is pure indigo, and, by weighing it, we find the per centage of real indigo in the sample.

Another process, somewhat similar, was recommended by Mr Chevreul, a French chemist. He treated the powdered indigo first with water, then with alcohol, and afterwards with muriatic acid. The following is the result of his experiment, taking a hundred parts:—

| | | |
|---|---|---|
| Treated with water, | A green matter united to ammonia, A little deoxidized indigo, Extractive, Gum, | 12 parts. |
| Treated with alcohol, | Green matter, Red resin, A little indigo. | 30 — |
| Treated with muriatic acid, | Red resin, | 6 — |
| | Carbonate of lime, | 2 — |
| | Red oxide of iron, | 2 — |
| | Alumina, | 3 |
| There remained, | Silica, | 3 — |
| | Pure indigo, | 45 — |
| | | 100 — |

Although these processes give a much nearer and more certain approximation to the true value of indigo than the mere comparison of samples by the eye, still they are not direct enough, and require too much nice management to be resorted to generally in the dye-house. Those, indeed, who are most affected by a bad bargain, and ought to be most interested in any process that would enable them to avoid loss, and who have the requisite time and means to try such experiments, do not seem impressed with their importance. Neither are they always possessed of the requisite dexterity of manipulation, and moreover, in general, seem unwilling to devote half a day to ascertain what they suppose can be accomplished, at least approximately, in an hour's time by comparison.

Another method has been discovered by Dr Dana of Lowell, United States, for ascertaining the real value of commercial indigo. He directs, that the grains of indigo, reduced to a very fine powder, be put into a small glass flask, with two and a half ounces, by measure, of a solution of carbonate of soda, of from 30° to 35° of strength by Twaddle's hydrometer; after boiling for a few minutes, 8 grains of crystals of chloride of tin (crystallized red spirits,) are to be added, and the whole boiled for half an hour. By this means the indigo is dissolved, and the liquor appears of a yellow colour. 6 grains of bichromate of potash (red chrome,) is dissolved in 6 ounces of water; and, when the flask is withdrawn from the lamp, this solution of chrome is added, which precipitates the indigo blue, along with a trace of the indigo red, leaving the other ingredients in solution. The whole is next to be poured upon a double weighed filter, and the precipitate washed with 1 oz. of muriatic acid diluted with 3 oz. of boiling water, and afterwards with hot water, till nothing but water returns. Then separate, dry, and weigh, the filters, and make a note of the weight of the precipitate; burn one filter paper against the other, and their difference in weight is the quantity of silica contained in the indigo. This, deducted from the weight of the precipitate, gives the quantity of pure indigo. Mr Walter Crum, who communicated the above to the British Association in 1841, added, that carbonate of soda, with protoxide of tin, dissolves indigo, and forms a yellow solution, but so slowly, that he doubts if all the 10 grains are acted upon. He thinks Dr Dana must mean soda-ash, which contains a notable quantity of caustic soda, but a much weaker solution of caustic soda would answer the purpose.

Pure indigo, besides its great importance as a dye-drug, possesses some of the most important and interesting chemical properties, which are as yet not very well understood. Some of these we shall notice before entering upon its practical value. If pure indigo be heated to about 550° Fah. it sublimes, producing a beautiful transparent vapour of a reddish-violet colour, which adheres to the sides of the vessel in which it is sublimed, or on the top of the cinder which is left in long needle-shaped crystals.

Mr Crum, whose investigations have thrown great light upon the chemical nature and properties of indigo, employed for its sublimation the covers of two platinum crucibles, about three inches diameter, and, of such a form that, when placed with their concave sides inward, they were about three-eighths of an inch distant in the middle. About the centre of the lower lid were placed thinly, about ten grains of indigo, precipitated from the dyers' vat, in small lumps about a grain each; then, having put on the cover, the flame of a spirit-lamp was applied beneath the cover containing the indigo. The indigo immediately began to melt with a hissing noise, which, when it had nearly ceased, the lamp was withdrawn, and the whole allowed to cool. On removing the cover, the sublimed indigo was found planted on its inner surface, and a little remained upon the charred matter, and was easily removed. In this way he obtained from 18 to 20 per cent. of the indigo employed.*

As few working men have access to platinum crucible covers to repeat this experiment, we state, that it may be successfully repeated by taking a thin porcelain plate, or a sheet of iron or copper, with the indigo placed upon it, and covering it with a pretty large watch-glass; when the plate under the indigo is heated by a lamp, the vapours very soon make their appearance; and, towards the close, the glass appears black, owing to the coating of indigo which adheres to its inner surface. To obtain pure indigo for this experiment, the easiest method is to take a little of the yellow solution of the indigo vat. Adding to this a few drops of muriatic acid, to dissolve tne salts of lime, the blue indigo falls to the bottom, and may readily be collected upon a filter, then washed and dried. A very pretty and easy method has been described by T. Taylor, Esq., which is as follows: "Any quantity of indigo is to be reduced to powder, and mixed with about half its weight of plaster of Paris. To these materials so much water is to be added, as will bring the whole to a thin paste. This is to be spread evenly upon an iron plate to the depth of the eighth of an inch, and allowed to remain exposed to the air, or to a gentle heat, until it is tolerably dry. If the heat of a large spirit-lamp be now applied to the under surface of the plate, the indigo begins to smoke, emits a disgusting odour, and in a few minutes is covered over with a dense purple-red vapour, which condenses into brilliant flattened prisms, or plates of an intense copper-colour, forming a thick velvety coating over the surface immediately exposed to heat. When this ceases to appear, the heat is of course to be withdrawn; and when cold, the sublimed crystals may be readily lifted or swept off, without in the slightest disturbing the subjacent mass. The operation is exceedingly beautiful to look at, is effected in a few minutes, and any quantity of materials might be acted upon. For ultimate analysis, the sublimed indigo must be previously washed with alcohol or ether. The object of the plaster is to prevent the indigo from cracking during drying."†

Pure indigo, whether obtained by sublimation, or other chemical means, is of a deep blue, approaching to violet. If scratched or rubbed, it has a strong copper hue, and a metallic lustre. It has neither taste nor smell, and is remarkable for its neutral properties. It is insoluble in water, alcohol, ether, alkalis, and dilute acids. Its chemical composition is 6 atoms carbon, 5 hydrogen, 1 nitrogen, and 2 oxygen.

If indigo be thrown into fused hydrate of potash, its blue colour disappears: it dissolves, and is partly decomposed along with the water of the alkaline hydrate; hydrogen, and ammoniacal gases are evolved, while carbonic acid, and another acid named valerianic acid, having properties similar to acetic acid, are formed, and combine with the potash. By digesting this mixture with a little sulphuric acid, the alkali combines with it, and the new acid crystallizes. This acid, combined with alkalis, and other bases, forms a very interesting series of salts.

If indigo, in fine powder, be added to nitric acid, diluted with seven or eight times its weight of water, and a gentle heat be applied, it dissolves with effervescence, forming a yellow liquid. After standing a little, this liquid may be decanted from any resinous matter found during the process, and concentrated by evaporation; and speedily there will be found deposited a quantity of yellowish-white crystals, having a sourish-bitter taste, and requiring about 100 parts of cold water for their solution. This was formerly termed indigotic acid, but is now called anilic acid, from the species and name of one of the plants which yield indigo. It combines with all known bases, forming salts, which have generally a yellow colour. It gives a blood-red colour to solutions of the persalts of iron.

If indigo be added to strong nitric acid, and heat be applied, it quickly dissolves, evolving a great quantity of nitrous gas. On allowing the liquid to cool, a large quantity of semitransparent yellow crystals are formed, having a very bitter taste. This is what was, till lately, called carbazotic acid; but this name has been changed to picric acid.

To obtain it in a purer state, the crystals obtained by the above operation are to be washed in cold water, and then boiled in water sufficient to dissolve them; next filtering the liquid and allowing it to cool. The acid again crystallizes in yellow brilliant prisms. This acid may also be obtained by the action of nitric acid upon anilic acid.

Picric acid is very permanent in its constitution. When fused in chlorine or with iodine, it is not decomposed, nor does a solution of chlorine affect it, Cold sulphuric acid has no action upon it, but dissolves it when hot. Boiling hydrochloric acid does not act upon it, but nitro-muriatic acid, (aqua regia), dissolves it with difficulty. It acts like a strong acid upon metallic oxides, dissolving them, and forming peculiar crystallizable salts. Its salts are yellow; they detonate strongly when sharply heated, and sometimes by a blow, particularly the potash salt. When a little of it is gradually heated in a glass tube, it first fuses, and then suddenly explodes, breaking the tube to pieces. Care is necessary in making this experiment, as the fragments of glass may injure the face.

This acid is an excellent test for the presence of potash in any fluid. A solution of it in alcohol produces a bright yellow crystalline precipitate, even in a diluted solution of the alkali. It is thus more sensible than the chloride of platinum, commonly employed for the detection of potash; for that reagent does not produce a precipitate in dilute solutions of that alkali.

When indigo is acted upon by very diluted fuming nitric acid, it unites with two atoms more of oxygen, and is consequently converted into a new substance, which has received the name of *isatine.* This substance under the influence of alkalis, absorbs one equivalent more of water, and assumes an acid character, and is termed *isatinic acid.* This acid combines with other substances forming a series of compounds, the nature of which is not yet very well known. Chromic acid has a similar action upon indigo as nitric acid.

When indigo in the dry state is brought into contact with dry chlorine, no chemical action is observed; but when indigo suspended in water is subjected to the action of chlorine, several new products are formed. When the fluid thus acted upon is distilled, a fluid product in minute quantity passes over with the distilled water, and collects under it in the receiver, in the form of white scales, which has been termed *chlorindoptin.* It is sparingly soluble in water, but copiously in alcohol. The substance which remains in the retort is found to be a mixture of several new products. On being dissolved in boiling alcohol, it yields on cooling, red prismatic crystals of a bitter taste, and very insoluble in water; this has been named *chlorisatin.* It dissolves in a solution of caustic potash, producing a red colour. The salts of lead give with this solution a yellow precipitate, which becomes a fine scarlet by standing. The salts of copper, (bluestone, &c.,) give a brown, which becomes blood-red by exposure to the air.

In the alcoholic solution another substance is found, having an equivalent more of chlorine than that named above; this is termed *bichlorisatin.* Its properties, however, are analogous to those of chlorisatin; its solution in potash gives a yellow precipitate with the salts of lead, but does not alter by exposure to the air; and with the copper salts it gives a yellowish brown, which passes to blood red.

When chlorine is passed through a solution of chlorisatin, another substance named *chloronile* is formed. This crystallizes in scales of a brass yellow colour, and, when dissolved by potash, gives a beautiful purple colour.

If indigo in powder be added to a solution of caustic potash, of specific gravity 1·35 (7 Twaddell), and boiled, an orange yellow salt is formed. The solution of the boiled mass becomes blue in the air from absorption of oxygen, like a solution of white indigo, and blue indigo precipitates.

Besides the compounds resulting from the action of nitric acid and chlorine upon indigo, there are several others which

* Annals of Philosophy.

† Chemical Gazette.

from their true characters being still little known, we have not thought it necessary to enumerate. Some practical dyer may indeed be inclined to ask, what those already noticed have to do with dyeing? We are sorry that with respect to some of them, we cannot give any satisfactory answer to the question; but the same question was asked, when chemists first intimated that chromic acid produced yellow salts when combined with lead; yet this simple hint has completely revolutionized various departments of dyeing, as we shall have occasion to notice when we come to treat of the mineral colouring matters; and the action of chromic acid upon indigo, as already observed, has been both a source of annoyance and advantage to the dyer. Previous to the use of alkaline substances with the salts of lead, dyers seldom could get an evenly *chrome* green; the chromic acid being set at liberty acted upon the indigo which was upon the yarn, destroying in part the blue colour, after which the green was all light yellow *blains.* These annoyances are still felt where the new process of working the lead solution with an alkali is not practised. But this same action of chromic acid upon indigo has been taken advantage of by calico printers, when they want a white pattern on a blue ground. The pattern is printed upon the cloth with the oxide of a metal which yields its oxygen easily to other substances, such as copper and zinc; the goods are afterwards dyed blue by passing them through the vat; but the parts upon which these metallic salts are printed, resist the dye, by a process which will afterwards be described, so that the piece, when finished, is a blue ground with a white pattern. But after the blue vats have been wrought for some time, they cannot be used for this purpose, owing to the weakness of the indigo, and consequently the length of time necessary to keep in the goods to produce the required shade. So that these *resist pastes* are in a manner washed off, and the pattern spoiled. Now, in place of throwing out as useless, vats thus exhausted, as formerly done, the cloth is dyed blue without resists, and after being slightly scoured and washed, they are passed through a strong solution of chromate of potash, and dried in the shade; the required pattern is then printed on the cloth with a mixture of oxalic and tartaric acids made into a paste by gum or clay. The potash in union with the chromic acid is taken up by these acids, and the chromic acid being set at liberty, acts on the indigo, and a white pattern is produced. This ingenious process was discovered by a German chemist.

The following table exhibits the composition of those substances which we have briefly described as resulting from the action of nitric acid and chlorine upon indigo. It may be required for reference:—

| Name. | Carbon. | Hydrogen. | Oxygen. | Nitrogen. | Chlorine. | Water. |
|---|---|---|---|---|---|---|
| Indigo, - - - - | 16 | 5 | 2 | 1 | 0 | 0 |
| Isatine, - - | 16 | 5 | 4 | 1 | 0 | 0 |
| Isatinic acid, - - | 16 | 5 | 4 | 1 | 0 | 1 |
| Anilic, or indigotic acid, | 14 | 4 | 9 | 1 | 0 | 1 |
| Picric, or carbazotic, acid, | 12 | 2 | 13 | 3 | 0 | 1 |
| Chlorindoptin, - | 16 | 4 | 2 | 0 | 4 | 0 |
| Chlorisatin, - - | 16 | 4 | 3 | 1 | 1 | 0 |
| Bichlorisatin, - - | 16 | 4 | 3 | 1 | 2 | 0 |
| Chloranile, - - | 6 | 0 | 2 | 0 | 2 | 0 |
| Valerianic, - - | 10 | 9 | 3 | 0 | 0 | 1 |

## IRON FOUNDING.

### SECTION II.—(*Continued from page* 105.)

Amongst the great variety of work denominated green sand moulding, much and varied contrivance is displayed in the structure of the moulds. In particular, the management of cores is a matter of very considerable importance, and the malformation of them is a prolific source of failure in the production of sound castings.

Cores are especially useful for forming vacancies in castings. Their forms may be long, and proportionably small in diameter, or winding and otherwise intricate; and seeing that they are necessarily surrounded by the iron when cast, they ought to have as much as may be the qualities of firmness of substance and openness of pores. Cores, as has already been stated in the first paper, are commonly composed of rock sand and sea sand. The former, having a proportion of clay in its composition, to which it owes its powerful cohesiveness when dried, serves very well as a material for short cores that rest in the green sand at both ends, as open communication with it is thus afforded for the free escape of the air in the interstices of the cores. But when rock sand is used for cores of considerable length, (which of course are surrounded on all sides by the iron, except the small imbedded portions at the extremities, by which alone the air can escape) it requires to be moderated by the admixture of free sand as a counteractant to the clay. The clay communicates the necessary cohesiveness to the material of the core: the sand on the contrary, loose and open, renders it less binding and more porous. Free sand alone is also employed in the construction of confined cores, that they may afterwards be easily extracted, as the sand has naturally no power of cohesion. Wanting cohesiveness, it must be tempered to a proper consistency by the addition of clay and water, yest, or the refuse of the pease-meal used for light flat moulding purposes. In the use of the last material, it must be accurately proportioned to the sand with which it is mixed. The clay-water is in ordinary cases made use of as a cement, and the yest only in very particular circumstances. For large compact masses of core, the common green sand may be used, as illustrated in both examples given in our last communication.

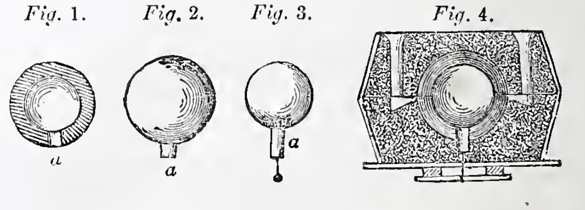
The longer cores are stiffened by iron wires, and small rods which are bent if necessary to the form of the cores. These rods are enveloped in the core in the progress of its formation, and are afterwards extracted from the casting. The cores of considerable length are pierced longitudinally by wires for the escape of the air; or in cases in which this is impracticable on account of bends, or angles in the core, a piece of string is laid in the sand, alongside the stiffening wires, which is afterwards drawn out when the core is dry, leaving its perforation behind it.

With all these precautions for securing the strength of cores, and for the all-important purpose of letting off the air, blown holes do occur at times in castings, formed by the air thrown off the cores into the iron.

When the bearings of cores at the extremities are considered unfit for steadying them, they are further sustained by steeples stuck into the sand at several places in their length. These are simply nails with broad flat heads, and several of them being set into the sand, and projecting above it just as much as the thickness of metal, the core is placed upon them and sustained steadily in its place; the steeples are of course buried in the casting, and the points of them projecting outside, are chipped off in the course of dressing it. Chaplets* are also used to bear up cores having plane surfaces.

An excellent example of the use of free-sand cores is found in the construction of bomb-shell mouldings. The form of a bomb-shell, it may be stated, is simply a hollow sphere of cast-iron, having one small round hole as a passage to the interior, termed the fuse-hole, as in the annexed sectional view, (fig. 1), in which *a* is the fuse-hole. The pattern of the shell is a plain globe

*Fig.* 1. *Fig.* 2. *Fig.* 3. *Fig.* 4.




(fig. 2), of the same external diameter as itself, having a core print *a* upon it, answering to the fuse-hole, and of the same diameter. Fig. 3, represents the core, of which the diameter is the same as that of the interior of the shell; it has a projection *a* to form the fuse-hole. The whole core is formed in a box which opens in two semispherical parts to allow the core to be extracted. A piece of double-twisted wire is enveloped in the core, projecting at the neck with a loop at the outer end. By this wire the core is to be held down. Fig. 4, is a section of the moulding box and the moulding, showing the core in its situation, and the applications for holding it there by means of the wire, which passes through the bottom of the moulding, and is

* In last article, by a slight overlook, these objects are named steeples.

locked on the under side. Two gates also are represented, by which the metal is poured.

It is evident, then, that when the casting is formed, the fuse-hole is the only exit for the core sand in the interior. The material of the core ought therefore to be easily friable, as it can be broken down only by external blows. Accordingly, it is formed of free sand, so tempered with clay water or other binding principle, as to acquire just such a tenacity as will enable it to bear the action of the metal. The fuse-hole core is made of rock sand to enable it to bear the weight of the body of the core, and to withstand the strains to which it may be subjected. The surfaces of the core and of the exterior moulding, are washed with a mixture of blackening and water to communicate smooth interior and exterior surfaces to the shell. A pricker is sent into the heart of the core through the neck, forming by this means a passage for the escape of the air confined throughout its substance.

Our next examples are intended to illustrate generally the manner of constructing patterns, in an exigency which frequently occurs, namely, when certain portions of a pattern enveloped in the sand, project horizontally beyond other parts which are above them. Were the pattern, in such circumstances, to be formed in one piece, it obviously could not be withdrawn from the sand without breaking up the moulding at the parts referred to. This idea may be explained by the annexed figures; *a*, *b*, fig. 5, being respectively a cone and a sphere. Were these objects buried in the sand, as shown in the fig. and then drawn out, the base of the cone would describe the space included in the vertical lines *o o*, and would also of course remove the overlying sand. A similar result would ensue with the sphere. The lower part of the mould of the sphere would be left as it is, while the upper part between the lines *o o*, would be destroyed. The simple remedy for these cases would be to invert the position of *a*, as shown in fig. 6, and to mould the sphere *b*, so as to have its largest horizontal diameter at the surface of the sand. While the under half could thus be moulded in the under box, the upper half would be rammed up in the upper box. As in these, so in all other instances, patterns, or parts of patterns, to be capable of being moulded in sand, must in their general outline taper from the surface of the sand downward. For this reason, such parts of the surface of a pattern as may be intended to be vertical, when it is being moulded, are never made truly so. A slight tapering inclination is given them, that they may leave the sand the more readily.

*Fig.* 5.

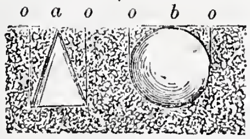
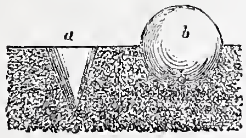



*Fig.* 6.




A variety of other peculiar circumstances, however, frequently occur, which require special methods of management. For example, a common sheave requires a particular, and an elegant process, to execute the moulding of it. Figure 7. is a diametrical section of one. The circumference, it will be observed, is grooved out semicircularly at *a a*, and a hole *o* is made through the centre. The object is now, to mould the pattern in such a manner as that the portion of sand forming the groove *a a* may be left in its place when the pattern is drawn out. The pattern, fig. 8, must be formed in two halves, separated by a plane *a a* passing through the centre of the groove. These halves are prevented from shifting by pins *n n*, or this may also be effected by a button on the centre of the one, fitting a recess in the other, as in the figure. There are also prints at *o o*, for supporting the core.

*Fig.* 7.


*Fig.* 8.

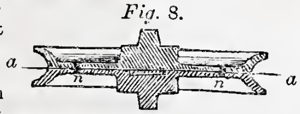
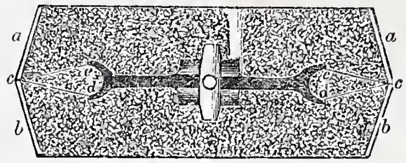



Fig. 9. represents, in section, the moulding of the pulley. *a a*, and *b b*, are the boxes. The pattern is first bedded in the lower box, and a parting *c d* formed from the under rim to the edge of the box. The ring of sand *c d e* is, in the next place, rammed about the pattern, filling the groove, and its upper parting surface *c e* is brought from the upper rim. Again, the upper box is placed on the other, and also filled.

The ramming being now completed, and the gate pin set, the

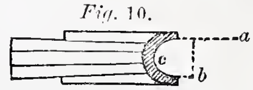
*Fig.* 9.




box *a a* is lifted off, carrying with it the impression of the upper side of the pattern. The upper half of the pattern being free, is lifted away, and the box *a a* replaced. The whole is now inverted, and the box *b b* is lifted off, thus permitting the remaining part of the pattern to be removed, which being done, and the moulding blackened and smoothed, and the core *o* set in, the box is replaced, and the two are finally reinverted. It will be observed, that the annular core *c d e* is never lifted from its situation during the process, and when the two boxes are linked together, it is wedged in on every side, and thus all possibility of shifting is removed.

Where there may not be facilities for turning the patterns of pulleys of large diameter, the grooves are cored out in the moulding. For this purpose, a core-print, running round the pattern, is provided in the making, as sketched in fig. 10, which is a section of the rim of a wheel supposed to be made with arms. The print is indicated by the dotted lines, and a core of the sectional form *a b c* is constructed in a core-box for the purpose. As there are only two boxes for the moulding, the pattern is mostly imbedded in the under one, the parting being formed on a level with the core print at *a*. It is not necessary that the core be all one piece; it may, for convenience, be formed in several segments.

*Fig.* 10.




We shall now select a fluted stove-pipe, as an example of another variety of adaptation. Fig. 11. is a transverse sectional view of the pipe, which may be supposed to be about five inches diameter, six feet long, and three-sixteenths of an inch thick. It will be observed, that the core, or interior of the surface, the pipe, follows in form the exterior surface, the object being to make the pipe as light as possible, otherwise a round core might have served the purpose.

*Fig.* 11.

To determine, then, the method of casting this pipe:—It is to be noted, in the first place, as a general rule, that all cylindrical bodies of any considerable length, are moulded in two boxes, one half in each. Agreeably to this, the patterns are usually divided longitudinally in two halves. Referring to fig. 12., which is a cross section of the stove-pipe pattern, the line *a a* represents the main division, which would suffice for a pattern having a plain exterior. For this column, however, deep as the flutes are, subdivisions are necessary, to render the moulding of it practicable. For it is easily seen that the angles *b*, *b*, *b*, *b*, immediately adjoining the parting *a a*, overhang the bottom of the hollows between *a* and *b*, and therefore, if the patterns were drawn vertically out of the sand, they must break away the intervening portions of sand that occupy these hollows. Such parts of the pattern require to be removed laterally, and for this purpose, each half is made in three divisions, as represented at *c c c c*, dovetailed to one another—allowing the smaller pieces to slide off the larger. Fig. 13. represents the core-box for the pipe. It is, like the pattern, parted in two at *a a*. In the top of the upper half a loose piece *b*, the length of the box, is provided,

*Fig.* 12.

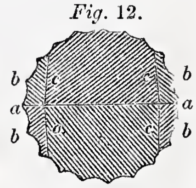
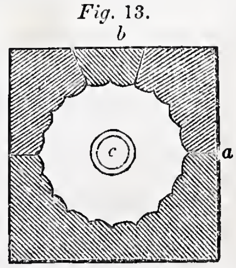



*Fig.* 13.

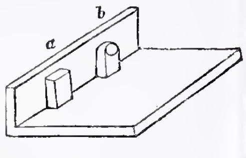


which being removed, the sand for the core may be introduced by the opening; *c* is the core bar, which runs the whole length for the purpose of stiffening the core.

The pattern having been moulded in the usual manner, one half in each box, so that the plane *a a*, fig. 12, coincides with the parting of the sand, the middle piece of each half is first drawn out, when the smaller pieces may next be removed laterally, to make way for the core.

On this principle of construction, in similar circumstances, patterns are generally made. Fitting strips, for example, when applied to the vertical face of a pattern, below the surface of the moulding, are attached to it by sliding dovetails. Core prints are very often placed in such circumstances. In fig. 14, which is the pattern of a flanged plate, *a* and *b* are two core prints, which, instead of being dovetailed to the pattern, are carried quite down to the plate, which is moulded in an inverted position; these continuations clear the way for the prints themselves, which would otherwise break the moulding. After the cores are introduced, these temporary vacancies are filled up with the aid of smooth strips of wood, and the figure of the moulding restored. In general, core prints, on vertical faces of patterns, are carried up to the parting surface with the view of making their own passage, which is afterwards closed over the core.

*Fig.* 14.




Take, for our next example, a pannelled octagon column or post. It presents a more complicated structure than the stove-pipe, and to render it workable in the sand, the pannels are, each by itself, made separable from the body of the pattern, being attached to it by screw-nails, which are driven off the inside. The pattern is divided into two principal halves. When it is moulded, the pannels, of which there are four to each half, are fixed on. When the parts of the box are separated, exposing each a half interior of the pattern, the screws are returned and withdrawn, thus leaving the frame of the pattern at liberty from the pannels. It is next lifted out, and these being disengaged from the sand by tapping, are likewise taken out in order. In this way, a complete external moulding of the column is formed. The core, constructed upon a stout bar, is next inserted, and the box closed upon it.

Of the use of plates in moulding, an example has already been given in last paper in the account of the moulding of an engine sole-plate. A different application will now be described in relation to the moulding of a lathe-bed. Fig. 15. is an end view of the bed; *a a* are the upper sliding surfaces, overhanging the sides; these are connected and stiffened at several parts by deep flanges joining them. The surfaces *a a*, as they are the most important parts of the bed, are, according to the general rule, moulded undermost, the object being to secure a sound structure at these parts, free from blown holes and impurities, which collect more or less towards the upper side of every casting. Fig. 16. is a section of the pattern and moulding. The parts *a*, *a*, are simply attached by loose pins to the rest of the pattern. The first step is to bed the pattern in an inverted position thoroughly on the floor which is levelled and smoothed all about it. Plates *b*, *b*, extending the whole length of the pattern, are set along both sides of it, an inch or so apart, to support the sand exterior to the pattern. A series of small rods, either of wood or iron, is placed on each plate. These rods overhang it on the side next the pattern, from which, however, they must be at some distance. In this way, the rods form a projecting platform, by which the sand that would overhang the plate is sustained. If of wood, the rods are dipped in clay-water, that they may adhere to the sand. The moulding is now made up with sand, flush with the pattern within and without. The parting surface is formed, and covered in by the upper box in the usual manner, which, being lifted off, and the pattern having been loosened, it is drawn out, leaving the loose pieces *a*, *a*, imbedded in the three masses of sand *n*, *n*, *o*. The masses *n*, *n*, resting on the plates, are raised and moved aside by handles which are cast upon the plates, and project upwards. The pieces *a a* being thus relieved, are edged out from below the sand *o*, and removed. *n*, *n*, are replaced as before, guided by conical projections from the plates, and the moulding is covered in by the upper box.

*a* *Fig.* 15. *a*

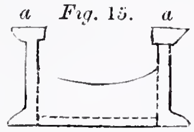
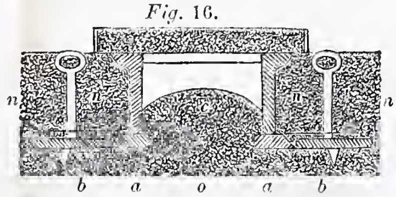


*Fig.* 16.




Plates are also employed in the moulds of bevel-wheel patterns for lifting the bodies of sand sunk between the arms. Frequently, too, in miscellaneous cases, where considerable depths of sand occur in the upper part of the mould, slips of wood are planted vertically in the masses, reaching upwards between the ribs of the upper box, their object being to bind the whole body of sand the more firmly together.

In our next article we shall endeavour to explain the process of dry-sand moulding.

## ANALYSIS OF LOCOMOTIVE ENGINES.

### CHAPTER II.

#### TECHNICAL DESCRIPTION AND DETAIL.

Example.—A Six-wheeled Locomotive Train Engine of the London and South-Western Railway, constructed (not designed) by Mr. W. Fairbairn of Manchester.

*(Illustrated by Two Plates.)*

In proceeding to the description of our second example of locomotive engines, it will be unnecessary to descend to that minuteness of popular detail which characterized our first article under this general head, given at page 93. The example now presented may be taken as a type of a numerous class of engines. One obvious general characteristic is the number of wheels upon which the engine runs, and in this respect it is distinguished from the four-wheeled engine of Messrs Bury & Co. The form of the boiler constitutes another general feature; and it will be again observed, that the fire-box casing, while it is rounded on the top concentrically with the cylindrical compartment of the boiler, is square on the front and back. In this point, also, it contrasts with the corresponding part in our first example, in which instance the fire-box casing is entirely cylindrical on a vertical axis. The material of the frame is another point of importance. In our present example, it consists principally of wood, while in the engine of Messrs Bury & Co., it consists of single bars of iron.* In both instances, as in the great majority of others, the method of four eccentrics is employed for working the valve gear.

To this introductory notice, we subjoin the following table of references and explanations of the plates, to which we shall have occasion hereafter to recur more particularly, in our general review of the various peculiarities of construction which characterized the engines of the various makers:—

*Enumeration of the Figures.*

Fig. 1. is a longitudinal elevation of the engine and boiler.

Fig. 2. is an end elevation, showing in section the hind-axle and wheels, and a front view of the fire-box casing.

Fig. 3. is an end elevation, showing the smoke-box partly in section.

Fig. 4. is a longitudinal section of the engine and boiler.

Fig. 5. is a cross section, midway between the fire-box and the smoke-box, showing principally the valve and reversing gear.

Fig. 6. is a cross section at the same place, presenting a view of the diving-axle and its appurtenances.

Figs. 7 to 23 are detail drawings of the more important portions of the engine, on a larger scale than the preceding figures.

Figs. 7 and 8. are longitudinal and cross sections of one of the steam cylinders.

* This peculiarity in the engine of Messrs. Bury & Co., gives it an air of great lightness compared with the other.

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Fig. 5.

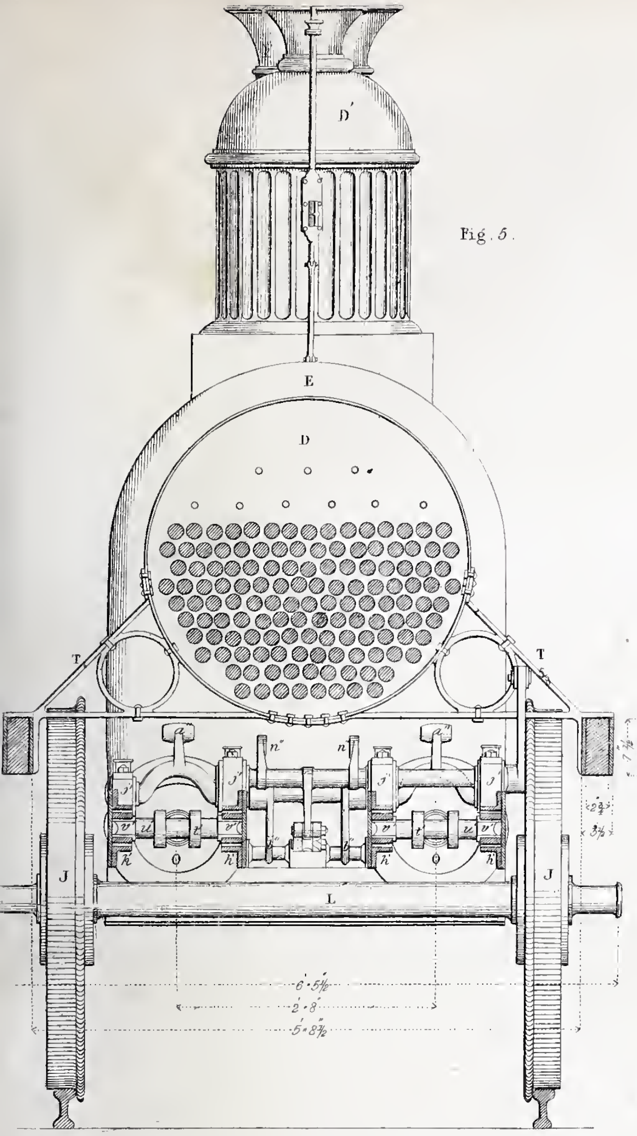
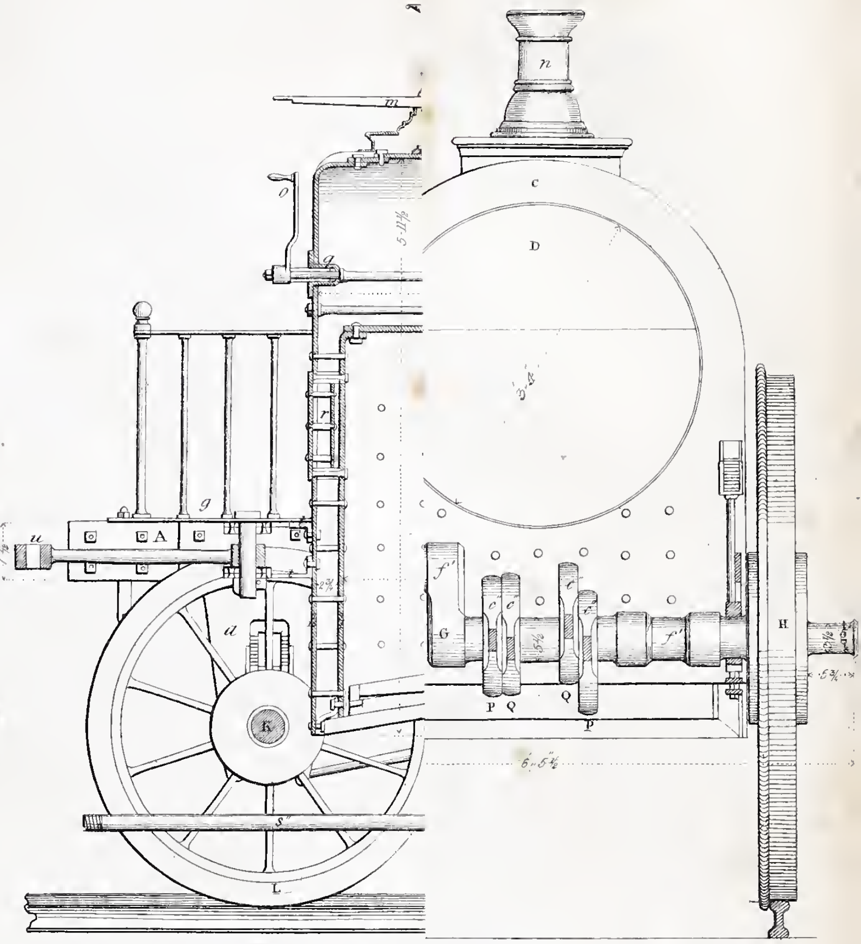



Fig. 6.




Scale of Feet for Figures

Fig. 18.

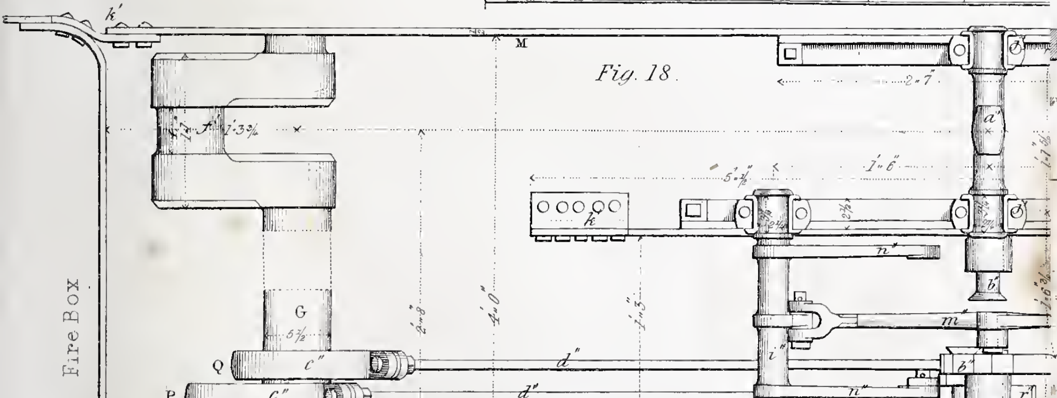
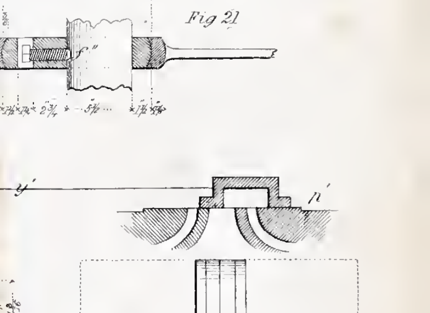



Fig 21



Scale of Feet for Figures 17 to

TRAIN ENGINE OF THE LONDON AND S

No. 8.A.

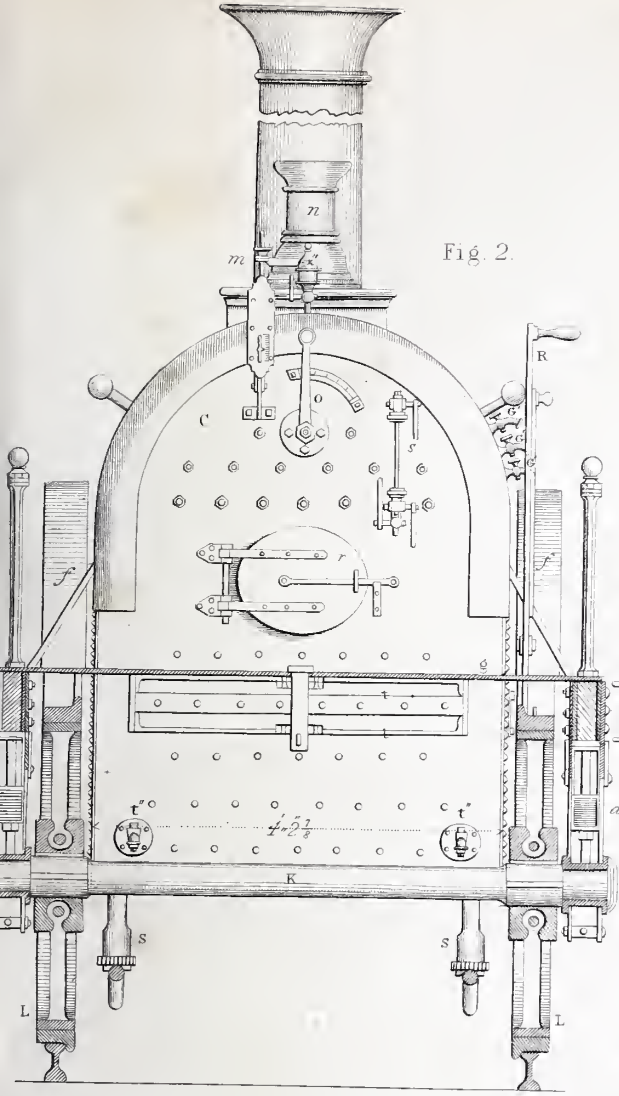
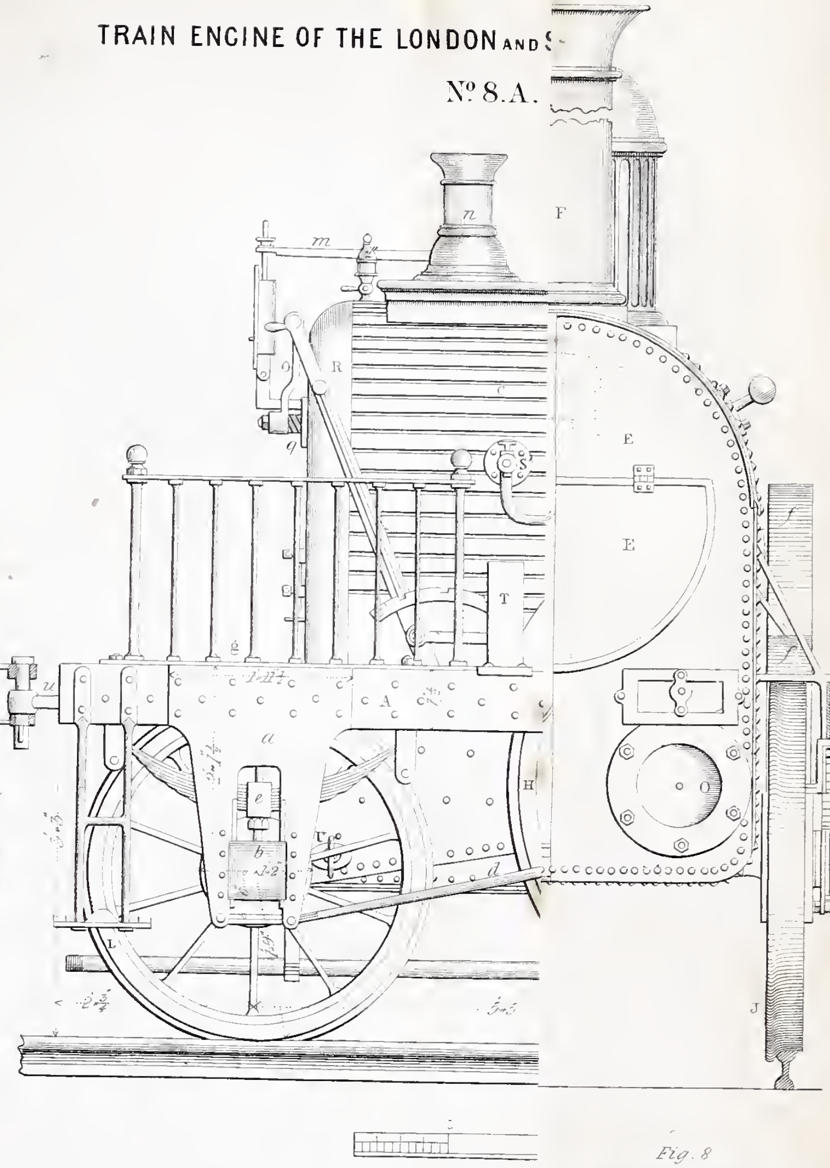


Fig. 2.



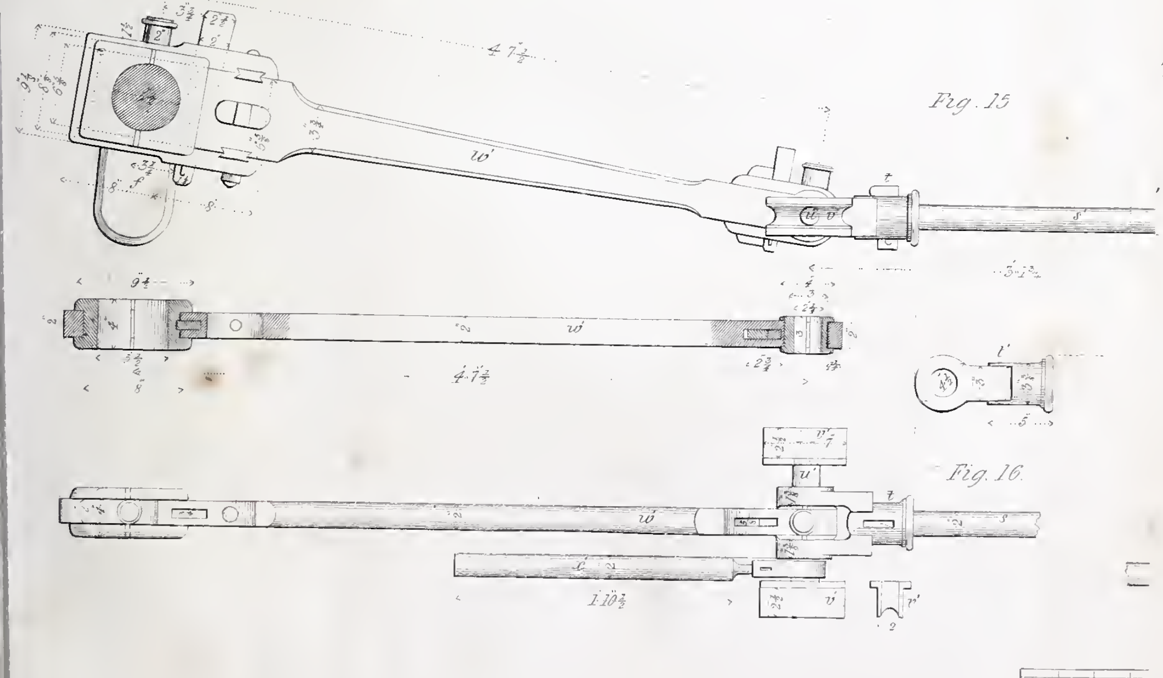


Fig. 15

Fig. 16.

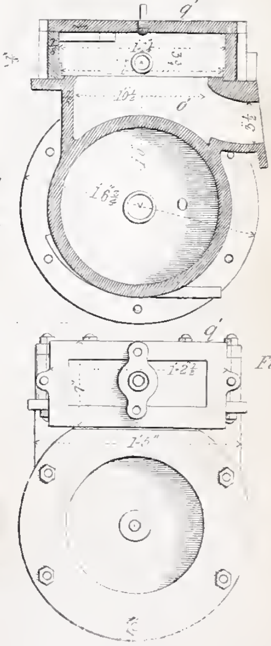


Fig. 8

Fig. 11

Fig. 9. is an end view of the top of the cylinder, with the lid on its place.
Fig. 10. is a plan of the upper side of the cylinder, with the steam-chest in its place, having the lid removed.
Fig. 11. is an end view of the bottom of the cylinder, with the lid on its place.
Figs. 12 and 13. are a plan of the upper side and edge view of the slide-valve, valve-spindle, and connecting-links.
Fig. 14. is an end view and diametrical section of the piston.
Fig. 15. is a side view of piston, piston-rod, connecting-rod, and crank.
Fig. 16. is a plan of the same, showing also the clutch and the plunger of the force-pump. Under the same figure are given sections of the connecting-rod and the clutch.
Fig. 17. is a side elevation of the reversing gear, and of the valve gear belonging to one cylinder. The dotted circle of four inches diameter indicates the effective sweep of the eccentrics; upon this circle are marked the positions of the centres of the eccentrics connected with the crank, represented in dotted lines.
Fig. 18. is a plan of ditto, representing also the crank-shaft, the interior wrought-iron frames, and the neighbouring portions of the boiler.
Fig. 19. is a detached side view of one of the frames M, M, with the slides and force-pump fixed to it, showing also the mode of staying the crank-shaft.
Fig. 20. is a plan of one of the forward eccentrics P.
Fig. 21. is a section of one of the eccentrics.
Fig. 22. is a plan and side view of one of the axle bushes, which are all of one inside diameter and length.
Fig. 23. is a face view of the regulator valve *x*, and steam-pipe *y*, one half of the valve being removed, so as to expose to view one half of the valve face.

*Literal References.*

A, longitudinal framing of the machine, consisting of battens of wood, strengthened by two plates of iron, one on each side, bolted together.
*a a a*, angle guards.
*b b b*, bushes for axles.
*c*, rail guards.
*d d d*, stay rods for axle guards.
*e e e*, spring-collars.
*f f*, sheaths for the wheels, bolted to the frame.
*g*, driver's platform.
B, end beam of frame.
*h*, the buffers.
*i*, a ring by which the engine may be connected.
C, fire-box casing.
*k*, fire-box.
*l*, fire-grate.
*m*, safety-valve and lever.
*n*, small chimney for leading off the escape steam.
*o*, handle for the regulator valve.
*p*, rod for ditto.
*q*, stuffing box.
*r*, charging door.
*s*, glass gauge.
*t*, *t*, two pieces rivetted to the fire-box casing, holding between them an upright pin, which passes through them.
*u*, a link connecting the tender with the engine.
D, the cylindrical or flue compartment of the boiler, with a brass dome, D′, enclosing a safety-valve.
*v*, double lever fixed on the rod *p*.
*w w*, two links, connecting the ends of the lever *v* with corresponding snugs on the regulator valve.
*x*, the regulator valve, the half of which is removed in figure 23, so as to expose to view one half of the valve face.
*y y*, the steam-pipe in two parts, connected by a neck,
*z*, and bolted to the tube plate of the smoke box.
*a′*, iron box erected on the boiler to receive the regulator valve, surmounted by a safety-valve similar to that upon the fire-box.
*b′*, flue tubes.
E, the smoke box.
*c′*, short three-way steam-pipe, connecting the steam-pipe *y* with the pipe *d′*
*d′*, *d′*, branch steam-pipes to the cylinders.
*e′*, eduction or blast-pipe.
F, chimney.
G, driving axle.
*f′ f′*, cranks. *g′*, journals.
H, driving wheels.
I, fore axle.
J, fore wheels.
K, hind axle.
L, hind wheels.
M M, two interior iron frames, running the whole distance between the fire-box and smoke-box. Their office is to sustain the slides for the guide-blocks of the engine in conjunction with the frames N, N, to steady the crank-axle, and to hold the pumps.
N, N, two shorter frames within the two former.
*h′*, *h′*, &c., stiff-kneed brackets, bolted to the frames M, M, N, N; upon the upper ones the bearings *j′ j′ j′* &c., are cast.
*i′*, *i′*, &c., slides bolted to the brackets *h′*, &c., with thin pieces of wood between them, shown by the blank spaces in the section, fig. 5.
*j′ j′ j′* &c., bearings cast upon the brackets *h′* &c., in which the journals of the valve and reversing gear are bedded.
*k′*, *k′* &c., angled pieces of wrought iron, by which the frames M, M; N, N, are bolted to the boiler.
*l′*, bush for affording interior hearings to the driving axle.
*m*, *m′*, wedge work for tightening up the bearings.
O, O, the steam cylinders.
*n′*, *n′*, the steam passages.
*o′*, the eduction passage.
*p′*, slide valve.
*q′*, valve casing.
*r′*, piston.
*s′*, piston-rod.
*t′*, clutch, keyed in the end of the piston-rod.
*u′*, clutch pin, traversing the clutch.
*v′*, *v′*, guide blocks on the ends of the clutch pin.
*w′*, connecting-rod.
*x′*, plunger of force pump s.
*y′*, slide-valve rod.
*z′*, links connecting the rod *y′*, with the valve lever *a″*.
*a″*, *a″*, valve levers.
*b″*, *b″*, double gab-pins on the lower ends of the levers *a″*, *a″*.
P, P, forward eccentrics; and Q, Q, backward eccentrics.
*c″*, *c″*, &c., eccentric straps.
*d″*, *d″*, &c., eccentric rods.
*e″*, *e″*, screwed bolts and cutters, for holding together the two parts of each eccentric.
*f″*, pinching screws for holding the eccentrics tight on the shaft.
R, starting handle, furnished with a sliding rod, which moves along the handle in a dovetailed groove, and which drops into notches in a circular segment of iron, (fig, 1,) for the purpose of fixing the handle in its position.
*h″*, rod connecting the handle with the reversing gear.
*i″ i′*, reversing shafts.
*k″*, lever on the first shaft *i″*, wrought by the handle R.
*l″*, *l″*, *m″*, levers &c., for working the second shaft *i″*.
*n″*, *n″*, *n″*, levers for working the eccentric rods, by the links *o″*, *o″*.
*o″*, *o″*, links connecting the eccentric gabs with the levers *n″*, &c.
*r″*, *r″*, forked gabs on the ends of the eccentric rods *d″* &c.
S, force pump, *x′*, the plunger.
*s″*, the feed-pipe communicating with the tender.
T T T, wrought-iron knees, supporting the boiler upon the frame A.

In this enumeration of the parts, we have not thought it necessary to particularize the dimensions, as these are given in considerable detail in the drawings.

## AGRICULTURE.

### CHAPTER II.

#### AGRICULTURAL CHEMISTRY AND PHYSIOLOGY.

We can only pretend here to attempt a brief outline of these two subjects. We must refer those seeking more extended information regarding them to the works of Professor Johnstone and Dr. Kemp.

When we glance around us, and see whole generations of men passing away—when we witness countless generations of all the different animals—when the geologists tell us that the land on which we stand was once the bed of an ocean—and that where the wave of the Southern Pacific now rolls in uninterrupted majesty, was once, probably, a continent—we are apt to think that everything is made but to be destroyed. But the truth is, that no material thing in this world ever is destroyed; and of the elements that formed the globe when it first came out of the hands of its great Creator, we have reason to believe that not a jot has ceased to be. If we consider any individual atom of matter, indeed, we may see clearly enough that it has changed its place and relation to other matters times innumerable; but still it is there, as it was at the beginning, undestroyed, and, as we have reason to think, indestructible. It may have been pent up in the entrails of the earth; cast hence by a volcanic eruption; may have then been appropriated by some vegetable, and converted into its frame; may then have passed into an animal, and, when that animal died, may have rotted and been reconverted into dust again, to be taken up by a plant; but there it is, the same identical atom of matter, just as it was, and just as it will be. All the matter upon the surface of the earth is continually undergoing a series of transitions. From soil and from the surrounding air and water do plants derive their structure and bulk; from plants do the animals that feed upon vegetables, in like manner, derive their bulk; and from plants and herbivorous animals do the flesh-feeding animals derive theirs. Then these animals die, and these same atoms of matter become soil, air, and water again. All the matter on the outside of the globe is thus passing from one state to another,—first, soil; next life; after these rottenness; and then soil again; and so on in an eternal cycle. The hand that writes these lines, and the eye that reads them, was once dust, even as that upon which we tread; and the time is coming, and that not far apart, when this same hand and that same eye will be dust again, to be trod upon by our successors; and then to form, perchance, the hands and eyes of their successors.

To trace this passage of matter from soil to plant, is the business of the farmer who would manage arable land satisfactorily, at least so far as to raise the crops; and to trace it from plant to animal, when he wishes to raise and fatten stock; and from both to putridity, when he comes to consider in what manner to restore fertility to his fields.

That portion of the surface lying over the subsoil, and which has, indeed, been mainly formed from the subsoil, thus becomes theoretically, as it always has been practically, a subject of great importance to the farmer. Thus, the manner in which the soil has been originally formed, becomes a matter of consequence, inasmuch as this will instruct us in the manner in which, notwithstanding, the farmer is continually turning part of it into crops, and selling them off his farm, he may yet keep it in sufficient quantity upon the land.

It is now admitted (we have not space to enter upon the proofs), that when this globe upon which we dwell was called into being, by the miraculous will of Him who made it, if any spiritual beings were in connexion with it, it was not through the medium of matter. At first no life was present upon it—not so much as a humble moss. Neither was there any soil, nor indeed anything, save bare rocks without verdure, and vast seas without an occupant. Still, the matter that now compose the structure of all vegetables and animals was then there. It becomes, then, an important question, Of what is this matter composed?—this matter the same in composition then in rocks and seas, as it is now not only in rocks and seas, but in men, beasts, and plants also?

The answer to this is, that the matter on the surface of the globe then, as now, is composed of various combinations of a few elementary bodies or substances, an elementary substance being one that cannot, do what we will, be separated or resolved into two others.

Chemistry has now discovered that there are fifty-four or fifty-five of such elementary bodies. Some of these, however, occur very rarely, and it will be sufficient for our purpose to consider the more striking properties of thirteen. These thirteen form our own structure, and, consequently, exist in our food; and, therefore, in abundance in the soil, air, and earth, from which, directly or indirectly, *our* food derives *its* food. Their names are carbon, oxygen, nitrogen, hydrogen, sulphur, phosphorus, potassium, sodium, calcium, magnesium, silicon,* iron, and chlorine. To these, although not existing in either animals or plants, but abundantly in the soil, we must add aluminum. Each of these demands a short separate account.

1. *Carbon.*—This element is very abundant. It forms a great part of our bodies, and of the structure of plants. It is, too, always present in the atmosphere, and is to be found in all fertile soils. It differs in appearance according to the manner in which the particles are aggregated together; but they are easily proved to be identical. The purest form of carbon is the diamond, which is believed to have been formed by the decomposition of vegetable structures under great pressure; a form of it derived from the mineral world is called graphite, and is used for making pencils. Wood-charcoal is a familiar instance of it, as derived from a vegetable; and burnt bones, or animal charcoal, as it is sometimes called, from the animal world. It is quite easy (and upon this depends the art of agriculture) to pass the same atom of carbon from mineral to vegetable, and from vegetable to animal. The graphite may, for instance, be converted into part of the structure of a turnip: this turnip, so formed, may be allowed to rot, and return this carbon to the soil; or it may, by the action of fire, be made to take the appearance of charcoal; or it may be given to an animal to eat. In this latter case, the carbon passes into the animal's structure, whence it may go to other animals that feed on it, be returned to the soil, or by fire be made to assume the appearance of animal charcoal.

2. *Oxygen.*—This element occurs in great abundance in us and in everything around us. When alone, it is always in a gaseous state; but it forms both liquid and solid compounds with other elements. It is an essential constituent of both air and water.

3. *Hydrogen.*—This, too, is a very abundant element, that is invariably present in every part of our structures. It is one of the constituents of water.

4. *Nitrogen.*—This element is present in almost all parts of man or animal, is one of the constituents of the atmosphere, and is *now* present in soil. But, as we shall by and by see, originally soil did not contain nitrogen.

The four elements, by uniting together in different proportions, form various compounds. Five of these are of such consequence to the scientific agriculturist, that, pressed as we are for space, we must mention them.

(*a.*) *Carbonic Acid.*—This is composed of carbon and oxygen, and is found wherever anything is burned or when an animal breathes. As stated above, carbon exists in great quantities in animals and plants; and, when we consider the immense quantity of it locked up in coal, which is extinct plants, and in chalk and limestone formations, which are nothing but extinct animals, or the remains of extinct animals, it is clear that, before animals and plants were created, the carbon that was intended to enter into their structure must have been in some other form. Many reasons lead us to believe that this form was carbonic acid, and that, at an early period in the world's history, the atmosphere contained it in very large quantities. This has been gradually abstracted from it by the

* Silicon is only found in plants, not in animals. In the mineral world it is most abundant.

trees and other vegetable beings, and part of this has from vegetables passed into animal structures.

(*b.*) *Water.*—This is composed of oxygen and hydrogen.

(*c.*) *Air.*—Air essentially consists of nitrogen and oxygen. It also always contains a little carbonic acid and some ammonia. This latter having been derived from animal putrefaction, of course, before the creation of the animal and vegetable world, the air would contain none of this ammonia.

(*d.*) *Ammonia.*—This is composed of nitrogen and hydrogen. It is never found in the mineral kingdom, but is always formed when animal and most vegetable structures undergo the process of rotting or putrefaction.

(*e.*) *Humus.*—If fertile soil (*i.e.*, soil of a darkish colour, in what the practical farmers call "heart") be boiled with carbonate of soda, and to the whole a little spirit of salt added, a dark substance falls to the bottom of the vessel. This is humus, and consists of carbon, oxygen, and hydrogen. It is formed when plants rot. Hence primitive soil contained no humus.

We now go on with the enumeration of the elements.

5. *Sulphur.*—This is familiarly called brimstone, and is essentially present in the structure of our animals and cultivated crops.

6. *Phosphorus.*—This element is likewise present in crops and animals.

7. *Potassium* is an element, the base of potash.

8. *Sodium* is also an element, and the base of soda.

9. *Calcium* is also an element, and the base of lime.

10. *Magnesium* is also an element, and the base of magnesia. All these four elements are essentially present in the structure of man, the domesticated animals, and the common crops of this country.

11. *Chlorine* is likewise an element, present, indeed, in but small quantities, but essentially present in all the objects of a farmer's attention.

12. *Iron.*—This metallic element is invariably and essentially present in both crops and flocks.

13. *Silicon* is the base of sand: is found in most crops, but in no animal.

14. *Aluminum* is the base of clay, present in soil, but not found in any vegetable, nor, by consequence, in any animal.

Assuming, then, that the early world was composed of water and bare rocks, these rocks being composed of various compounds of the above fourteen elements, and the whole surrounded by an atmosphere rich in carbonic acid, the gradual formation of soil becomes plain enough to understand. When (as we daily see going on around us) the surface of a rock is exposed to air and moisture, it gradually crumbles down. This is owing to the elements composing it, joining with the elements composing the water and the atmosphere. The crumbled mass thus formed, consisting of unions of carbon, oxygen, hydrogen, nitrogen, sulphur, phosphorus, potassium, sodium, magnesium, calcium, chlorine, iron, silicon, and aluminum, is the first step to the formation of a soil. Then, probably, came the creation of plants,—the first plants being, in all likelihood, those characterised by the small roots and extended leaves, as mosses, lichens, and ferns, and which are, by their construction, qualified to obtain much from the air and little from the ground.

These plants (like those that have succeeded them) consist of various compounds of the thirteen elements above enumerated. From the atmosphere these early plants would derive their necessary supply of carbon and nitrogen; from the water, hydrogen; and from the crumbling rock, sulphur, phosphorus, potassium, &c., chlorine, iron, and silicon.

All plants and animals have a limited duration; and the time would come when these primitive ferns would die. Their structure then decomposes the sulphur, phosphorus, potassium, &c. Chlorine and iron return to the elements. Carbon, oxygen, hydrogen, and nitrogen, so arrange themselves as to form humus and ammonia. These are added to the crumbling mass, and then we have perfect soil, such as that upon which we now grow our wheat.

It will be observed, too, that the plants would, by degrees, take away from the atmosphere its superfluous carbon. When perfect soil was first formed, we have reason to infer that other and more perfect plants were created, then animals, and, at last of all, man.

It is necessary to keep this formation of soil carefully in mind, inasmuch as, when rightly understood, it becomes the key to the scientific management of arable land. We now proceed to another topic.

Upon regarding the objects that compose the external world around us, we at once perceive that they may be divided into two classes,—those that have life and those that have not. To the former of these belong animals and plants, and to the latter stones, earths, minerals, &c. If we extend our observations, we see that all the living objects, whether animals or plants, are furnished with *organs*, which organs perform different functions. Thus, an ox has a liver that secretes bile, a heart that circulates his blood; and a tree has leaves, flowers, &c., which perform their several functions. Hence it is common to say, that living beings constitute the organic kingdom of nature. And as the objects composing dead matter, as soil, rock, manure, or the like, have no organs, but are composed of a homogeneous mass, they are put down as composing the inorganic kingdom of nature.

But besides this possession of organs, the members of the organic world are distinguished by three very important peculiarities. We will extract Dr. Lindley Kemp's account of them:—"Every organised being," writes that gentleman, in his 'Agricultural Physiology,' "takes its origin from a previously organised being, or it is generated; then it constantly keeps up its organisation, by appropriating and assimilating surrounding matter; or it is constantly nourishing itself; and, lastly, it ends in death,—that is, it not only gives over nourishing itself, but its structure loses its present appearance and state of combination, and becomes subject to the laws which regulate inorganic matter, viz., to the laws of chemistry. Thus the wheat plant takes its origin from a seed, which had formed part of a previously existing wheat plant; thus it obtains from the air and the soil surrounding it the matters necessary for its nutrition, and forms them into itself; and thus, too, when the autumn comes, it withers and dies, and, ultimately, if left alone, rots. Thus also man, the highest of the organised beings, springs from his parents, lives upon the animals and vegetables around him, and at last, when his hour is come, dies, and lapses into inorganic dust."

In order that any living being, whether plant or animal, may resist this last-mentioned influence of death, and remain alive, certain conditions must necessarily be present. In the first place, all living beings are furnished with a nourishing fluid, called sap in plants—blood in animals,—which is essential for the support of their frames, and which is perpetually being applied to and expended in nourishing their frames. As it is always thus being expended, it is clear that it must as constantly receive supplies from without. To such supplies we give the name of food. This food of plants consists of the chemical elements of which they stand in need, as they exist in the soil and water and air,—*i. e.*, in the inorganic world. But the food of animals, although composed of the same elements, must have previously formed part of an existing organised structure, either an animal or plant. Thus, if we took ammonia and made a sheep eat it, no part of the ammonia would go to form mutton; whereas, if we put it to a wheat plant growing in a flower-pot, the wheat plant would take it up and turn it into grain. This portion of the grain, formed out of the ammonia, then eat by a sheep, would be converted into its flesh.

Another condition necessary for the continuance of life is, that this same nourishing fluid, sap, or blood, must be frequently exposed to the air to be acted upon by it. This is done in plants at the leaves and in animals at the lungs. The changes produced by this respiration, as it is called, are, in the case of animals, the giving out of carbonic acid and the taking in of oxygen; and in plants the reverse—that is to say, the giving out of oxygen, and the taking in of carbonic acid.

Then a certain amount of heat is necessary to the continuance of all vital action. In the higher animals a very considerable heat is produced within themselves, and in even the humblest plant some. This is done by causing carbon, taken

in as food, to combine with oxygen taken in in animals at the lungs. When this combination takes place, carbonic acid is formed and heat generated.

Then, in animals, every part of the body is continually dying and being cast out of the system. If this excretion does not take place, the retained matter acts as a fatal poison. Ample provisions are, however, made for excreting the thirteen elements of which the body consists. The more important of the excretions are the dung, the urine, the sweat, and the excretion of carbonic acid at the lungs of animals.

To describe the various provisions made for the circulation of the nutrient fluid, or blood, or sap—the respiration or exposure of it to the air—the food of animals and plants—the manner in which heat is generated in them—and the function of excretion in animals—is far beyond our present limits. But they are so essential to a knowledge of scientific agriculture, that we must, as far as may be done in our brief space, give an outline of them.

1. *The Circulation of the Blood and Sap.*—This fluid is always moving through animal and vegetable structures, parting with its contents to them, and thus building up their increasing structures. It moves through particular vessels, the description of which we cannot here attempt. The basis of sap consists of a substance of the nature of sugar (*i. e.*, a compound of carbon, oxygen, and hydrogen). The reason of this is clear enough; for the greater part of the structure of plants is composed of these three elements, and, of course, this structure is composed out of the sap. But other substances than these are found in the structure of plants; and, accordingly, we find in the sap nitrogen, potassium, calcium, magnesium, sodium, silicon, iron, sulphur, phosphorus, and chlorine.

Farther, plants not only provide for their own structures, but they lay up a store of nutriment for the young embryo that they develop. This, too, is derived from the nourishing fluid or sap, and is familiarly known by the name of starch.

The blood of animals bears a great resemblance to the sap of plants. The basis is not, indeed, a compound of carbon, oxygen, and hydrogen only, like sugar, but one composed of these three elements, with the addition of nitrogen, called albumen, of which the white of egg is a good example. The reason of albumen being the basis of blood, is, that by far the larger proportion of animal structures is made up of these same four elements. Besides albumen, blood contains the other elementary substances of which animal structures consist,—potassium, sodium, calcium, magnesium, iron, sulphur, phosphorus, and chlorine.

As sap contains starch, necessary for the support of the young germ, so blood contains a particular substance called fat, which it deposits in different parts of the body, to serve as a store of future nutriment for the animal itself.

All the compound substances formed out of the blood and sap, to be applied to nourish the structures of animals and plants, admit of an arrangement into three divisions. The first of these is called—

(*a.*) The *Saccharine*, or *Sugary.*—The objects composing this division are composed of carbon, oxygen, and hydrogen, and the two latter are in the same proportion that they are in water. In animals, only one example of this class is to be found, viz., sugar as it exists in milk. It is composed as follows:—Carbon, 24; oxygen, 18; hydrogen, 18.

Sugar exists abundantly in most vegetables. Some other varieties exist; but the composition of vegetable sugar may be put down as exactly analogous to that of sugar of milk. Another very common saccharine proximate principle of vegetables is starch. It is composed of carbon, 24; oxygen, 20; and hydrogen, 20.

The following table exhibits the proportion per cent. of accharine proximate principles, as present in the usually cultivated crops of this country:—

| | | | | | |
|---|---|---|---|---|---|
| Wheat flour, | 55lbs. | in the 100 | Beans, . . | 40lbs. | in the 100 |
| Barley, . . | 60 | " | Peas, . . | 50 | " |
| Oats, . . | 60 | " | Potatoes . | 18 | " |
| Rye, . . | 60 | " | Mangel-wurzel, | 11 | " |
| Indian corn, | 70 | " | Turnips, . . | 9 | " |
| Rice, . . . | 75 | " | | | |

(*b.*) The *Oleaginous*, or *Oily.*—The compounds of this division are composed of carbon, oxygen, and hydrogen; but the two latter are *not* in the same proportion that they are in water. Both vegetable and animals' proximate principles of this class are either margarine or elaine,—margarine being solid,—elaine, liquid; or, what is still more common, a mixture of the two. The composition of the two is—

| | *Margarine.* | | *Elaine.* |
|---|---|---|---|
| Carbon, . . . . | 37 | Carbon, . . . . | 39 |
| Hydrogen, . . . . | 37 | Hydrogen, . . . . | 36 |
| Oxygen, . . . . | 4 | Oxygen, . . . . | 5 |

The following table shows the proportion per cent. of these oleaginous principles on our common crops:—

| | | | | | |
|---|---|---|---|---|---|
| Wheat flour, | $2\frac{1}{2}$lbs. | in the 100 | Beans and peas, | $2\frac{2}{5}$lb. | in the 100 |
| Bran, . . | $3\frac{1}{2}$ | " | Potats.&trnips. | $\frac{1}{5}$ | " |
| Barley, . . | $2\frac{2}{5}$ | " | Wheat straw, | $2\frac{2}{5}$ | " |
| Oats, . . | $5\frac{1}{2}$ | " | Oat do. | 4 | " |
| Indian corn, | $5\frac{1}{2}$ | " | Clover hay, | $3\frac{2}{5}$ | " |

The proportion of the oleaginous principles of animals varies according to their condition:—

(*c.*) *Albuminous*, or *Fleshy.*—These compounds consist of carbon, oxygen, hydrogen, nitrogen (usually about 15 per cent. of this element), and varying proportions of sulphur, phosphorus, potassium, iron, chlorine, and the other elements so often mentioned.

Albumen itself is one of the commonest of these principles. A very familiar example of it is white of egg. It exists in blood, the flesh, in sap, in many seeds, and in the structure of many trees and plants. It is composed as follows:—Carbon, 53; oxygen, 23; nitrogen, 15; hydrogen, 7.

The analysis of albuminous principles have not been sufficiently exact, as to enable us to state in what proportions the phosphorus, &c. exist in them. We, therefore, omit all mention of them.

Casein, or the principle of cheese, occurs in milk, and also in many plants, as in potatoes, turnips, bean meal, &c. It has been found to consist of—Carbon, 59; oxygen, 11; nitrogen, 21; hydrogen, 7.

Fibrin is an albuminous compound, only found in animals. It is very extensively diffused over the whole body. It consists of—Carbon, 52; oxygen, 23; nitrogen, 16; hydrogen, 7.

Gluten, on the other hand, is an albuminous compound, only found in vegetables, but very much resembling fibrin. It exists in cereal grains, many seeds, &c. It is composed of—Carbon, 55; oxygen, 21; nitrogen, 15; hydrogen, 7.

Gelatine is an albuminous principle belonging to animals. It exists abundantly in the bones and skin. The composition is—Carbon, 47; oxygen, 27; nitrogen, 16; hydrogen, 7.

The flesh of animals consists almost entirely of these albuminous principles, mixed up in *ripe* ones with oleaginous ones, or fat, or suet. The per centage of the albuminous compounds contained in the common crops, is shown by the following table:—

| | | | | | |
|---|---|---|---|---|---|
| Wheat flour, | 10 to 19 | per cent. | Beans, . | 24 to 28 | per cent. |
| Bran, . . . . | 16 | " | Peas, . . . | 24 | " |
| Barley, . . | 12 to 15 | " | Potatoes, . . | 2 | " |
| Oats, . . | 14 to 19 | " | Mangel-wurzel, | 2 | " |
| Indian corn, . . | 12 | " | Turnips, . . | $1\frac{1}{2}$ | " |
| Rice, . . . . | 7 | " | | | |

Although the quantity of sulphur, phosphorus, potassium, &c., iron, chlorine, and silicon, mixed up with each albuminous proximate principle, is not known, the aggregate quantity contained in common is indicated by the following table:—

| | | | |
|---|---|---|---|
| 1000 lbs. of | Wheat contain | 20 to 30 | lbs. of these elements. |
| " | Barley . . . . . | 30 | " |
| " | Oats . . . . . | 40 | " |
| " | Indian corn . . . | 15 | " |
| " | Beans and peas, . . | 30 | " |
| " | Wheat and barley straw, . . . | 50 | " |
| " | Oat straw, . . . . | 60 | " |
| " | Pea straw, . . . | 50 | " |
| " | Clover, . . . . | 90 | " |
| " | Potatoes, . . | 8 to 15 | " |
| " | Turnips, . . | 5 to 8 | " |

Another important animal principle belongs to none of these divisions. It is formed of phosphorus, oxygen, and calcium; is usually known by the name of phosphate of lime; and forms a greater part of the bones of animals.

These proximate principles or compounds unite together (along with some others of less importance, that our space forbids us to mention), in varying proportions, and, by so doing, form the various organs of animals and plants,—leaves, livers, kidneys, bark, flesh, seeds, &c. &c.

We are now prepared to understand the important subject of the food both of plants and animals. We commence with that of the former.

The sap of plants consists of the thirteen elements we have enumerated. These it is continually parting with to the plant to which it belongs. Consequently, it requires a continual supply of them. It obtains from the air some carbon, oxygen, and nitrogen; from water, hydrogen and more oxygen; and all its supply of the other nine from the soil, which soil, we have previously seen, contains them. All that is necessary is, that these elements in soil be in such a state as to be soluble in water. When this is the case, the roots take them up, and they are at once added to the sap.

When a crop is removed, of course so much of what was soil is carried away from the field upon which it was grown. The subsoil, by crumbling down and forming soluble compounds, tends to compensate for what is taken away; and we promote this recruiting of the soil from the subsoil, by ploughing and subsoil ploughing. The soil is, likewise, thus renovated, when the old-fashioned plan of fallowing is followed. But upon most land in this country can we obtain a crop every year, or nearly every year, by following these practices only? Of the great quantity of soil carried away by cropping, very imperfect ideas seem to prevail. If we inquire, for instance, how much is carried off by the not uncommon four-shift rotation of turnips, wheat, grass and clover, and, in the fourth year, oats, we shall find it enormous. We will assume that the turnip crop is 30 tons to the acre, the wheat 40 bushels, the oat 70 bushels, and the rye-grass 1 ton, and the clover amongst it half a ton.

We will begin with the wheat. Wheat of 40 bushels, each weighing 64 lbs., and the straw weighing twice as much as the grain, would take from the ground—

| | |
|---|---|
| Potassium, | 48 lbs. |
| Sodium, | 5 " |
| Calcium, | 19 " |
| Magnesium, | 16 " |
| Iron, | 3 " |
| Phosphorus, | 32 " |
| Sulphur, | 16 " |
| Chlorine, | 2 " |
| Silica, | 192 " |
| Total, | 333 lbs. |

The grass and clover would abstract—

| | |
|---|---|
| Potassium, | 38 lbs. |
| Sodium, | 12 " |
| Calcium, | 45 " |
| Magnesium, | 7 " |
| Phosphorus, | 15 " |
| Sulphur, | 10 " |
| Chlorine, | 4 " |
| Silica, | 78 " |
| Total, | 207 lbs. |

Supposing that the weight of each bushel of the oats was 42 lbs., and that the straw weighs two-thirds more than the grain, the oat crop would take away from an acre—

| | |
|---|---|
| Potassium and sodium, | 105 lbs. |
| Calcium | 28 " |
| Magnesium, | 15 " |
| Iron, | 7 " |
| Phosphorus, | 30 " |
| Sulphur, | 20 " |
| Chlorine, | 12 " |
| Silica, | 224 " |
| Total, | 441 lbs. |

The 30 tons of turnips would take away—

| | |
|---|---|
| Potassium, | 300 lbs. |
| Sodium, | 58 " |
| Calcium, | 170 " |
| Magnesium, | 40 " |
| Iron, | 10 " |
| Phosphorus, | 80 " |
| Sulphur, | 126 " |
| Chlorine, | 10 " |
| Silica, | 45 " |
| Total, | 919 lbs. |

That is to say, the four crops would take away from the acre 1,822 lbs., or 16 cwts., and in twenty years a farmer, getting such crops, would abstract 80 cwts. from an acre; or, every year, he, on an average, takes away from an acre about 4 cwts.

In these calculations we have left out of account the carbon and nitrogen furnished by the soil (in the shape of humus and ammonia) to the plant.

But no land can, in this country, stand such cropping; and it is found necessary to add these elements to the soil, to furnish food to the plants we wish to grow. Such food we call manure.

The most important manure is farm-yard. It consists of the excreted and effete portions of animals (consequently containing all the thirteen necessary elements) and straw. The following is the composition of a ton of pretty-rotten farm-yard manure:—

| | |
|---|---|
| Organic matter, containing humus and ammonia, | 553 lbs. |
| Silica, | 62 " |
| Phosphoric acid (*i. e.* phosphorus and oxygen), | 17 " |
| Sulphuric acid (*i. e.* sulphur and oxygen), | 7 " |
| Carbonic acid, | 11 " |
| Potash (*i. e.* potassium and oxygen), | 7 " |
| Magnesia (*i. e.* magnesium and oxygen), | 4 " |
| Soda (*i. e.* sodium and oxygen), | 6 " |
| Iron, | 4 " |
| Chlorine, | 7 " |
| Water and loss, | 2240 " |

Guano is another manure. It is composed of ammonia, phosphorus, and the remaining of the thirteen elements of vegetables, excepting potassium, in which it is deficient.

Bones are another common manure. They contain beside ammonia (*i. e.* when rotten), phosphorus, calcium, magnesium, iron, chlorine, and silicon.

In the constitution of other manure, we must refer the reader to Professor Johnston's 'Lectures,' or to Dr. Kemp's 'Agricultural Physiology.'

The food of animals will now be as intelligible as that of plants. The blood, besides supplying the body with the elements necessary to make up its various structures, has to furnish it with sufficient of them to make up its daily waste in the way of excretion. Both these are done by the albuminous proximate principles of either animals or plants. The digestive organs of different animals are so arranged as to suit better to these albuminous principles, drawn from animals, rather than vegetables, and *vice versâ*. Thus, the small stomach of the dog is intended for assimilating the concentrated albuminous principles of animals; that of an ox, the diluted ones of vegetables; while the medium-sized one of man can manage either with equal facility.

Animals, likewise, require a constant supply of carbon to be united in their bodies with oxygen, to form the animal heat. This is derived from either saccharine or oleaginous proximate principles. Either of these, when taken in superabundant quantity, is deposited around the kidneys, under the skin, and among the interstices of muscles, as fat. As animal food is most relished when in this state, to produce it is the object of the farmer.

# GEOGRAPHY.

## CHAPTER I.

### HISTORY AND PROGRESS OF GEOGRAPHICAL DISCOVERY.

The term Geography means, literally, a "written description of the earth," being derived from two *Greek* words having this signification. Geography might be made, therefore, to comprehend a description of everything both upon the earth and under its surface: of land and water—of mountains, plains, seas, and oceans—of plants, trees, and shrubs—of every species of land and water animals—and of man in his moral, religious, social, and political conditions. Geography, in this sense, might comprehend a description of the earth as one of the planets of the solar system, revolving round its own axis every twenty-four hours, producing day and night; and round the sun in a year, producing the alternations of the seasons. It might also include a description of the composition of the different rocks and soils on the surface of the earth, of the various strata which are said to constitute its crust, of the animal and vegetable remains found in these strata, with disquisitions on their history, formation, &c. Geography, however, would thus be made to include the sciences of botany, zoology, astronomy, geology, and mineralogy; and although no geographical treatise would be complete without, to some extent, calling in the aid of these sciences, the term geography is generally used in a much more restricted sense, and is made to signify that science which determines or ascertains all the external facts relative to the various countries on the globe, which render them fit or unfit for the abode, the comfort, the happiness, and the civilization of man.

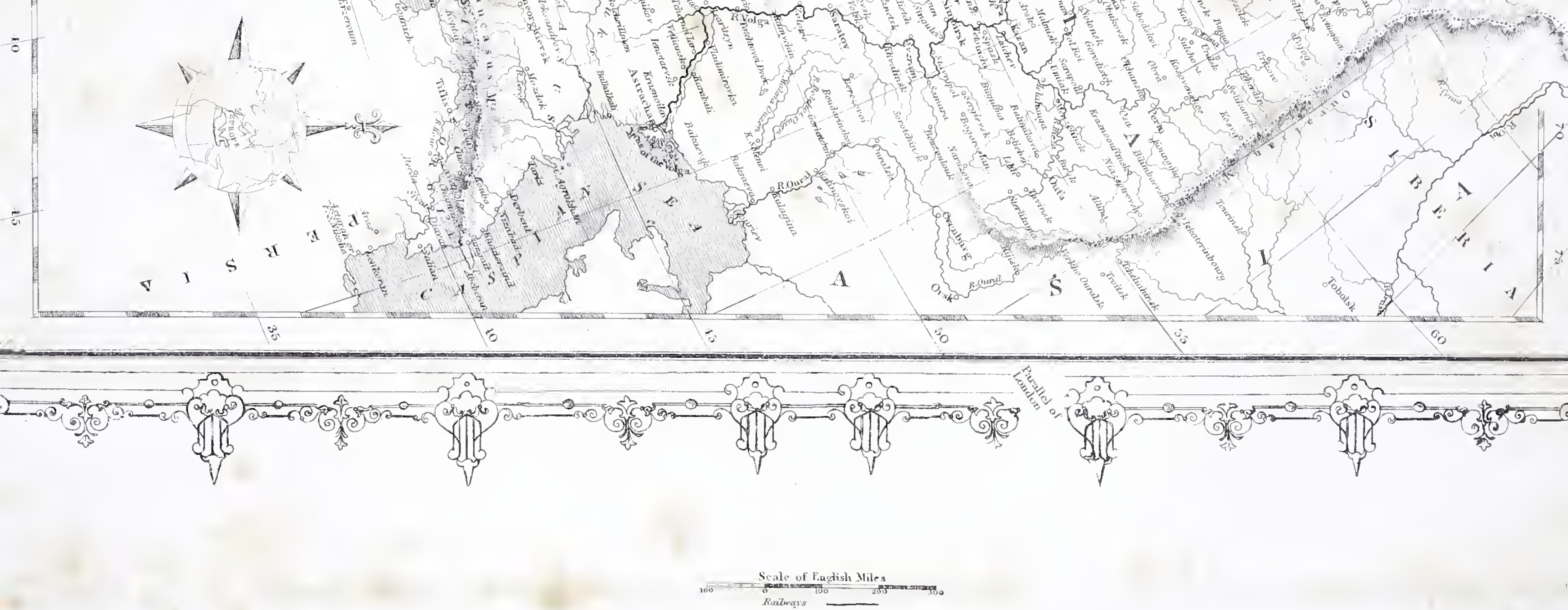
Geography is a description, then, of the different countries, kingdoms, states, cities, &c., on the earth's surface, and of everything therein, relating to the advancement and amelioration of the human race. Its object is to ascertain, in every country, the proportions and situations of land and water, internal seas, lakes, and rivers—the size, elevation, and position of the different mountains—the extent and course of the rivers—the nature and position of swamps and bogs—the extent of the plains, &c.; to ascertain also the nature of the soil and vegetation, whether they are adapted for agricultural purposes, for grazing, and for the raising of food and clothing for man—the climate must be taken into account as bearing in a marked degree upon the health, subsistence, and civilization of the inhabitants. It must also be borne in mind, that no country ever rose to a prominent position in the scale of civilization, unless possessed of ample capabilities for trade and commerce; everything, therefore, which can, either directly or indirectly, originate and extend the commercial prosperity of a nation, whether mineral wealth, agricultural productions, animal or vegetable life, must be included in a treatise on geography.

A general knowledge of geography is now considered so indispensably necessary for every one, whatever his rank or station in life, that the rudiments of the science are taught among the elementary branches of education. No one can open a book of history, of voyages, or of travels, or even a common newspaper, without meeting stumbling-blocks in every page, and without losing a great portion of the instruction and information they contain, unless he be in possession of an accurate knowledge of geography. An individual ignorant of this science is unfit to enter upon any commercial employment with advantage: he is liable to be imposed upon on all occasions; he will listen with credulity to the most absurd statements from every traveller or travelling impostor who may come in his way, and who may find it profitable to turn his ignorance to account. Even those who ought to know better are easily deceived and misled by the fallacious statements which are given by writers of voyages and travels, as to the condition and circumstances of those countries and their inhabitants which they visit and describe. Suppose, for example, a person of wealth and fashion, with a very deficient knowledge of the continental languages, and with meagre powers of observation and description, to make the tour of Europe; he will cross the Channel, travel through France in a *diligence* or carriage, call at a number of inns, dine at the *table d'hote*, converse in broken French with the waiters and a few strangers, visit some of the most remarkable places in the towns he passes through; he will then cross the Alps and visit Italy in the same cursory manner, very probably without being able to speak a word of Italian, recross the Alps, sail down the Rhine, and return home, after an absence of only a few months. Such a person may have taken "notes" on his journey; and, on his return to England, he sits down quite coolly, and fancies himself admirably prepared to write his "Sketches of Europe," his "Rambles on the Rhine," his "Six Months in a Catholic Country," or his "Tour on the Continent," in which he gives a detailed account of the manners, customs, institutions, laws, religion, politics, and, in short, as minute and elaborate a description of every country he has passed through, as if he had resided in it, and studied its manners and constitution for a lifetime! His book is read; it is pleasantly written; it contains some amusing anecdotes; it flatters the national and deep-rooted prejudices of the Englishman. It tells him, that, when compared to the continental nations, he enjoys religious and political liberty in its most extended sense; that his religion is not worn as a cloak, but reigns over the empire of the heart; that true charity and Christian brotherhood are only to be found in the British islands, where splendid and time-honoured educational and charitable institutions are the fruits of a true and disinterested spirit of charity among a people, who are so patriotic as to glory in being allowed the honour of paying fifty-two millions sterling per annum, of taxes for the public good! On the Continent, what a sad contrast! There, religious and political liberty is bound in fetters; the poor benighted and deluded inhabitants must think and act as their superiors desire; they have no law of primogeniture, the patrimonial estate of the father being equally divided among the children; there, a man's position in society does not depend upon his birth and fortune, but upon his character and respectability; a peasant may dine at the same *table d'hote* with a king or a prince; they are so foolishly happy and light-hearted as to be very fond of music and dancing and other innocent pastimes; they pay few taxes, and food and clothing are, consequently, low-priced, so that they produce manufactures at a cheaper rate than the English, but of course they cannot be of so fine a quality, not being made in Britain. Such is generally the twaddle with which our modern and fashionable traveller fills his book; he knows no more of the countries he describes, and is as incapable of passing a correct judgment on their institutions, laws, manners, or customs, as a Chinese mandarin would be of giving his countrymen a true picture of England and the English, by landing at Southampton, travelling to London, thence to Birmingham, York, Manchester, Liverpool, and back to Southampton, in a railway carriage.

An individual possessing a thorough knowledge of geography—of the manners, customs, peculiarities, laws, and religion of the different countries of the globe, based on information derived from *standard* authorities on these subjects, and on statistical records, will smile at the shallow, prejudiced, and one-sided statements which daily meet his view in newspapers and elsewhere, and which proceed from writers whose object it is to exhibit persons and things as they would wish them to be, or as they see them through their contracted and distorted vision, and *not* as they really are. Is the social, moral, and religious condition of a private family to be better understood, judged of, and described by an entire stranger, after a visit of a few hours, than by an intelligent member of that family itself, who, on all other subjects, proves himself to be an impartial and indubitable authority, and who, in this case, necessarily knows intimately and thoroughly the most minute particulars? What is true, therefore, in the case of a private family, is equally true of

# EUROPE.


Scale of English Miles



SIBERIA
ASIA
PERSIA
CASPIAN SEA
Caucasus Mts
Ourals Mts
Parallel of London
Scale of English Miles
100 0 100 200 300
Railways
Kazan
Simbirsk
Saratov
Astrachan
Orenburg
Tobolsk
Iekaterinbourg
Perm
Oufa
Samara
Tiflis
Derbent
Lenkoran
R. Volga
R. Oural
R. Terek
R. Kour
35
40
45
50
55
60
70
75
10
15

nations; we must look upon a nation as made up of so many different families, and each family of so many different individuals; and although a few peculiarities may exist, which are so common to all the members, as to become distinguishing characteristics of families and of nations, still it is too much the custom of the present day to judge of the whole from one of its most minute parts, and we would beg seriously to caution the reader against statements which he may see or hear derogatory to the character of a nation, which are so prominently paraded by newspaper correspondents, &c., and which are generally made to serve the purposes of some peculiar religious or political creed.

A thorough and practical knowledge of geography enlarges the intellect and expands the soul; and, next to actually visiting the different nations on the earth's surface themselves, it contributes materially to originate in the mind of its possessor feelings of universal charity and benevolence—to make him look upon all men as brethren—and to enable him to see the powerful influence of wickedness and crime in hastening the downfall, as well of private individuals as of nations.

The writings of Moses contain the earliest authentic information on record regarding those ancient nations in the east, with whom the Jews had any direct or indirect communication. He relates that, 1700 B.C., the Midianites, who inhabited the country between the rivers Euphrates and Indus, to the north of the Persian Gulf, carried on a traffic with the Egyptians, passing through Palestine. The geographical knowledge of the Jews, however, was very limited. 500 B.C., they certainly knew something of Asia Minor, Egypt, Arabia, Assyria, and Armenia; but Mount Caucasus on the north, Ethiopia on the south, the Archipelago on the west, and the river Euphrates on the east, constituted the utmost limits of their known world. They believed, in common with all the ancient nations, that the earth was a flat plain, and that their own individual nation occupied its centre; that it was immoveable and fixed, and that the sun, moon, and stars performed their daily revolutions around it. The early Greeks held the same opinions; and they believed, moreover, that at some great and inaccessible distance, the earth was peopled with pigmies and giants. Most of the ancient nations also believed that the extreme verge of the flat and circular plain, whose centre they occupied, terminated in a tremendous chaotic gulf of impenetrable darkness; and as it was the interest of the early explorers of unknown regions, who wished to monopolise trade and commerce, to originate and perpetuate these absurd notions, and to magnify the dangers they had to encounter, the spirit of inquiry and curiosity was thus repressed, and the advantages of commercial intercourse with distant nations were long unknown. To this cause may be mainly attributed the very slight knowledge which was possessed, in those early ages, by nations tolerably advanced in civilization.

The most enterprising people of antiquity of which we have any account were the Phœnicians, who inhabited a small but exceedingly fertile district of country, extending along the eastern coast of the Mediterranean. Their chief towns were Tyre and Sidon—so often mentioned in Scripture history,—Aradus, Acco (now St. Jean d'Acre), and Berytus (now Beirout). In Joshua xix. 28, 29, "Zidon" is mentioned as a "great city," and "Tyre" as a "strong city," when the Israelites took possession of the land of Canaan; so that, whether or not the Phœnicians dwelt originally on the shores of the Red Sea, or of the Persian Gulf, as asserted by some, they must have settled on the coast of the Mediterranean at a very early period. Mount Lebanon supplied them with wood for shipbuilding; the town of Sarepta, or Zarephath, afforded them iron and copper; and, upwards of 1,000 years before the Christian era, they had navigated the whole of the Mediterranean, and founded the colonies of Hippo, Hadramentum, Utica, Tunes, Carthage, and Gades (Cadiz). They traded with India by the caravans of Arabia and Babylon; and it is related by Herodotus, although he does not vouch for the accuracy of the statement, that they circumnavigated Africa, sailing down the Red Sea, and landing at Alexandria, after an absence of rather less than three years.

The early Grecians had a very limited knowledge of geography. 500 B.C., they were merely acquainted with the western part of Asia Minor, the sea-coast of Egypt and Lybia, and a small portion of the south of Italy. The Egyptians were equally, if not more ignorant; so that the most enlightened people of those times scarcely knew anything of the extent, position, or even the existence of any country, except the borders of those which immediately surrounded their own.

Soon after the commencement of the 5th century, before the Christian era, however, the Grecians are said to have got possession of some of the Phœnician charts, and they extended their discoveries along the Mediterranean, and founded colonies in Sicily, Sardinia, Corsica, and even in some of the southern provinces of Spain.

About this time flourished the celebrated historian, Herodotus, who may be styled the father of geography, as well as of history. He travelled over all the northern parts of Africa, and traced the river Nile to the 11th degree of north latitude, as far as its western branch; beyond which point little is known even at the present day. In Asia, he visited Tyre, Babylon, and, in all probability, Suza; and travelled through the greater part of Asia Minor. In Europe, he visited part of Southern Russia, and the Greek colonies along the shores of the Black Sea. He also traced the river Danube almost to its source, travelled through the whole of Greece, and visited the South of Italy. Besides personally visiting these different places, Herodotus never lost an opportunity, during his travels, of acquiring the most correct information regarding those countries which he was unable to visit; so that, in this manner, he was acquainted with a great part of Poland and European Russia, with Western Tartary, with the greater part of the countries on the river Indus, and with Arabia.

During the age of Herodotus, the celebrated city of Carthage (already mentioned as an old Phœnician colony on the coast of Africa, in the state now called Tunis), reached its highest point of commercial prosperity. At an early period, the Carthagenians took possession of Malta (then celebrated for its cloth manufactures), of Gozo and Lampedoza, and subsequently of the Balearic and Lipari islands, the former of which were then famous for the production of wine, oil, and fine wool; they had also settlements all along the northern coast of Africa, from Cyréne to the Pillars of Hercules on the Straits of Gibraltar. B.C. 480, they had acquired the island of Sardinia by conquest, and some time afterwards they despatched two fleets to explore the western coasts of Africa and Europe. The first was commanded by Hanno, their king, and "consisted of 60 ships of 50 oars each, and a body of men and women, to the number of 30,000, with provisions and other necessaries." He passed the Straits of Gibraltar, near which he founded several cities; sailed round the west coast of Africa; discovered the Canary Islands and Madeira; and, having advanced as far south as Sierra Leone, he was obliged to return for want of provisions. The second expedition was commanded by Himilco, and sailed round the coast of Portugal as far as Œstrymnon Cape (supposed to be Cape Finisterre). Whether it proceeded farther or not, is uncertain; but certain it is, that, B.C. 400, the Carthagenians were acquainted with the northern provinces of Spain, and even with the British islands. They were not, however, the first foreign nation that visited Britain; for there is every reason to believe that the Phœnicians traded in *tin* with the inhabitants of Cornwall at a much earlier period. The power of the Carthagenians was first curtailed by their military reverses, in their attempts to take possession of Sicily, and finally destroyed, and Carthage rased to the ground by the Romans, B.C. 146; their colonies on the Straits of Gibraltar and elsewhere were thus neglected and forgotten, and the key to their discoveries and extensive trade completely lost.

In this century also (5th B.C.) lived the illustrious Hip-

pocrates, the father of medicine. He prosecuted his researches into very many countries, in the investigation of the influence of different climates upon the human constitution. In his travels he almost followed the footsteps of Herodotus; and he devoted so much attention to the physical aspects of the various countries he visited, that he may justly be regarded as the founder of the science of Physical Geography.

About 340 years before the Christian era, Aristotle, the famous philosopher, directed his powerful mind to the study of geography. He collected all the scattered information then extant on the subject; reduced it into a systematic form; deduced from it the spherical figure of the earth—the fundamental principle of the science; and, having, digested and arranged all these facts, he put them into the hands of his royal pupil, Alexander the Great, to enable him the better to concert his plans for the subjugation of the world. This mighty prince extended his conquests over Greece, Asia Minor, Palestine, Egypt, and Persia; and he penetrated as far into India as the river Sutlej, the eastern branch of the Indus. Upon the mind of Alexander, the instructions of Aristotle were not thrown away; he was imbued with a thorough zeal for the cultivation and advancement of the sciences, and he was no less solicitous to leave a correct geographical account of his expeditions, than to extend the boundaries of his empire. Even after his death, the science of geography was considerably indebted to one of his generals, who extended his conquests to the mouths of the river Ganges, and collected a great store of information regarding the countries thus visited. The continent of Asia was thus opened up to the commercial intercourse of Egypt and Greece, and the effects of the career of Alexander were long felt among the nations of the East.

Hitherto the Romans had reached no prominent position among surrounding nations; but, in their intercourse and wars with the Carthagenians, they learned the art of shipbuilding; and, about 50 years before the Christian era, they had extended their conquests in every direction. The Roman conquerors vied with each other in transmitting descriptions to Rome of the different nations they subdued, so that, by the beginning of our era, they were acquainted with all Europe south of the Baltic, including England, Scotland, Ireland, and the surrounding islands, with the countries on the Danube, Vistula, and even the Volga; with Africa as far south as the river Niger; and with Asia as far east as the Ganges. In the reign of Augustus, they discovered the monsoons, or the periodical winds of Asia—a circumstance which contributed more than any other to the extension o. their commercial intercourse with the eastern nations. Instead of travelling across the desert from Syria to the Euphrates, sailing down the Persian Gulf, and along the northern coast of the Arabian Sea to the mouth of the Indus, they now adopted a much less hazardous, less expensive, and more expeditious route, by sailing down the Red Sea; and having passed the Straits of Babelmandel, their ships were carried, by the aid of the south-west monsoon, to the Indian peninsula between the Ganges and Indus, and back again by the north-east monsoon in the course of the same year.

About A.D. 18, the accomplished Strabo finished the writing of his learned work on geography, which has descended in a tolerably complete condition to our time, and which gives a description of all the countries known to the Romans with surprising correctness and fidelity. A century later, Pliny, the naturalist, and Ptolemy, the astronomer, wrote, for that age, excellent treatises on geography; but the limits of the world, as known to the Romans, were little if at all extended, and the spirit of commercial enterprise and discovery, which was fostered by their conquests, was extinguished by that universal flood of darkness which followed the final overthrow of their empire by the barbarians.

The tide of civilization had not only been retarded, but thrown back, for several centuries, when Mohammed, the prophet, arose, and, in his zeal to propagate his religion over all the kingdoms of the earth, was the first to give a fresh impulse to the long-suspended intercourse between different nations. Mohammed himself had no other end in view than the extension of his temporal and spiritual dominion over the world; but, after a time, his successors became glutted with conquest, some of them laid aside the art of war, and began to cultivate and encourage the arts of peace. Under the peaceful sway of Harun-al-Rashid, literature and the arts were cultivated with zeal and perseverance. This prince displayed a love of justice and of commercial enterprise; his reign was the golden age of the Mohammedan nations; flourishing towns sprung up in every part of his dominions; traffic by land and by sea increased, and Bagdad became the seat of the sciences, as well as mistress of the world. His son and successor, Al-Maimon, was still more celebrated as a patron of literature; his court was the general resort of philosophers, mathematicians, physicians, and astronomers from all parts of the world; all the books and instruments which were serviceable for the promotion of science, and which had escaped the ravages of barbarism, were collected from every quarter; colleges and libraries were founded in all the chief towns of his empire; geographical knowledge was cultivated; and, in A.D. 833, this prince obtained the measurement of a degree of latitude in the desert of Sangiar, to enable him to ascertain the magnitude of the earth.

By the middle of the ninth century, the Arabians had formed a commercial connection with Madagascar, the Maldives, Ceylon, Sumatra, Java, and even with China. They had extended their conquests to Spain on the west, and to the river Ganges on the east; and wherever they carried their arms, their generals had orders to obtain correct information regarding every circumstance which might tend to throw light on the geography of the countries they subdued.

The darkness which overshadowed Europe, after the subversion of the Roman empire by the barbarians, was first faintly illuminated by the professors of Christianity. By them alone the desolating tide of ignorance and barbarism was stemmed; by them alone the arts and sciences were preserved from utter annihilation, till, in the middle of the eighth century, the Mohammedan invaders of Spain came to their aid, and contributed in a considerable degree to the diffusion of literature throughout Europe.

Alfred the Great, our illustrious and excellent Saxon king, who reigned over England during the latter part of the ninth century, was the first to enkindle a love of learning in Britain. In his childhood, he was sent to Rome to be educated; and from his very earliest years he displayed such aptitude for instruction, and such a love of literature, as bespoke the happy influence he would exert among his countrymen on his return to England. During his reign, he seized every opportunity, when not engaged in defending his kingdom against the inroads of the Danes, of encouraging all kinds of learning and every useful art. He himself translated some valuable authors, as well as several portions of the sacred Scriptures, into the Saxon tongue. He was the friend and correspondent of the most eminent scholars throughout Europe. He patronized travellers, and was the first founder of that naval power which was one day to be the dread and admiration of the world. From the writings of Alfred we have the earliest authentic account of Denmark, Norway, and Sweden. His information was based on the accounts he received from some Normans who penetrated these northern countries, and who, about a century after his time, carried their researches as far as Greenland and the Shetland Isles, where they founded colonies.

In A.D. 1001, a storm drove Biorn, a Norman navigator, from Greenland to the coast of North America, or, according to some, of Newfoundland; the part of the country which he discovered was often visited afterwards, and got the name of Vinland.

Towards the end of the eleventh century, the Crusades—wars undertaken by the Christians of the west to take Jerusalem and the Holy Land from the hands of the infidels—operated as a powerful means of advancing the civilization of Europe. By the intercourse which these crusades esta-

blished between the eastern and western nations—by the transference of the estates of the nobility who were engaged in them, into the hands of merchants—by the art of shipbuilding being cultivated, for the purpose of transporting armies to Palestine—by the crusaders who returned home, disseminating a knowledge of the various useful arts which they had seen on their travels—by the increase of trade and the acquisition of wealth in the maritime towns of Italy—political life received a powerful stimulus; the feudal system began to be broken up; commerce, which had slumbered for many centuries, was aroused; agriculture and all the useful arts were introduced and extended among the different nations of Europe; the sciences and the fine arts were revived in Italy; and, however chimerical the object of these Holy Wars may now seem, however deluded their promoters may appear in this enlightened age, when wars are undertaken against the native inhabitants of a country, whom we are pleased to call barbarians, for no other object than self-aggrandizement, one thing is *certain*, that nothing is recorded in history which exerted a greater influence in promoting the diffusion of knowledge, in extending trade and commerce, in extinguishing serfdom, or slavery, in Europe, and in advancing the civilization of mankind.

But these effects of the Crusades, in exciting the commercial enterprize of European nations, were not the only results which a desire for the promulgation of Christianity exerted, in promoting a knowledge of distant countries, and in extending the bounds of geographical discovery. Animated by the sincere and pious desire to christianize the heathen, not by fire and sword, like the followers of Mohammed, but by the benign influence of persuasion, missionaries of the Christian religion undertook long and painful journeys, during the eleventh, twelfth, and thirteenth centuries, through parts of Asia where European commerce had never penetrated, and where, particularly in the north of India, Tartary, China, and Japan, little is even yet known, except from the information which the accounts of these missionaries afford. The most distinguished of these travellers was Marco Polo, a noble Venetian, who, in 1272, accompanied his father, uncle, and two Dominican monks, as a missionary to the east. Marco Polo and his companions were the first Europeans who visited China proper; and after spending nearly twenty-five years in traversing, with the most indefatigable and unremitting labour, China, Tartary, Persia, and various other countries on the continent of Asia, and visiting Borneo, Java, Sumatra, the Nicobar islands, Ceylon, Madagascar, and other islands in the Indian and Pacific Oceans, he returned to Italy, and arrived at Venice, with his father and uncle, in 1295. Having taken part in the war which was then raging between the Venetians and the Genoese, he was taken prisoner by the latter, carried captive to Genoa, and, during the continuance of hostilities, was detained in prison. It was while immured within the walls of this dungeon that he wrote that narrative of his travels which continued for so long a period to be the only source of information to Europeans on every subject connected with oriental geography; and it is very much to be regretted that his misfortunes, after his return to his native land, prevented him from giving that detailed account of those countries he visited, which would have no doubt proved so advantageous to science, and which would have rendered him even more worthy of the name he so well deserves—the Humbolt of the thirteenth century.

That the mariner's compass was known in China, Japan, India, and Arabia, from periods of high antiquity, there can be little doubt; but to which of these nations the honour of the discovery ought to be justly awarded, will, in all probability, remain for ever a mystery. Certain it is, however, that the compass was unknown to the ancient Greeks and Romans, as well as to all modern European nations, till a knowledge of it was acquired by the crusaders in the twelfth century, and promulgated through Europe on their return from the east. The compass was used for purposes of navigation on the coast of Syria long before this period, as we learn from a MS., written in 1242, by Bailak Kibdjaki, where he describes the method of magnetizing the needle. A little after the date of this manuscript, it was generally known and partially used by European mariners; and having been greatly improved as a nautical instrument by Gioja, an Italian of Naples, about 1310, it soon became as indispensable to the seaman in guiding his bark through the trackless ocean, and in promoting geographical discovery, as the telescope became essential to the astronomer.

During the fourteenth century, few discoveries of any importance were made; but by the beginning of the fifteenth, the art of navigation began to improve, and that spirit of bold enterprise and discovery was awakened which was not again to slumber, till every sea and every ocean were traversed, and every portion of the habitable globe discovered and opened up by the mariners of Europe. The Portuguese were the first to attract the attention of the world by the fame of their naval discoveries. Having rid themselves of their oppressors, the Moors, and carried their warfare into the enemy's country, they were soon afterwards led to extend their discoveries round the west coast of Africa, which, beyond Cape Nun, was then totally unknown. In 1420 they discovered and took possession of Madeira; in 1433, Cape Nun was doubled for the first time; in 1445 they reached Senegal; in 1456, the Cape Verd Islands; in 1471, Prince's Island, St. Thomas, and Annobon; in 1484, they advanced to the mouth of the river Congo, in the kingdom of that name; and finally, in 1486, Bartholemy Diaz reached the southern point of Africa, which he doubled in a storm without knowing it, and called it the "Stormy Cape," for which King John II. of Portugal afterwards substituted the more pleasing name of the "Cape of Good Hope."

So noted did Portugal become under the influence of Prince Henry, the fourth son of King John I., as the great centre of attraction for the adventurous youth of other nations, that the bold and enterprising from all quarters flocked under her standard; and, among others, the celebrated Christopher Columbus, a native of Genoa, in Italy, allured by the hopes of employment as an explorer of unknown regions, came and settled in Lisbon about the year 1470.

Having been afforded the means of acquiring a good education, and having quickly distinguished himself for his proficiency in the sciences of geometry, geography, and astronomy, as then known, he entered upon a seafaring life at the early age of fourteen years. After being a considerable time occupied in voyaging between various ports of the Mediterranean, he set sail to Iceland, in 1467, on a voyage of discovery, which he extended 100 leagues beyond that island. It was some time after his return from these arctic seas, that he settled in Lisbon, and married the daughter of one of those navigators who had been employed by Prince Henry in the voyages of discovery on the coast of Africa. Having got possession of the papers, charts, journals, &c., of his father-in-law, and having discovered from these that the object of the Portuguese researches to the south was to discover a route to India, the idea of finding a nearer passage thither, by sailing westward, gradually arose in his mind. By a train of reasoning on the known sphericity of the earth, on the evidence of Marco Polo, which went to prove that the countries—China and Japan—which he visited, extended so far eastward as to approach Europe on the west, and on the facts that carved pieces of wood, trees of unknown species, and even two human bodies of a strange colour and unusual appearance, were all discovered and picked up on the western coast of Madeira, he arrived by degrees at the moral certainty of the truth of his conjectures, and his mind burned with enthusiasm for the means to prosecute his favourite schemes of exploration and discovery, to enable him to put his theories to the test of experiment.

But the sovereigns of Europe, either from inability to appreciate the force of his reasoning and the importance of his plans, or from parsimonious motives, all stood aloof. He was looked upon as an idle dreamer and reckless adventurer; by some he was rejected on account of his ignoble birth, by others, who fancied themselves learned, he was spurned be-

cause an obscure sailor had the audacity to anticipate the philosophical deductions which they ought to have made.

Columbus first applied for the means of discovering a nearer route to India, to the Genoese; but they had the sagacity to foresee that if any other route than that hitherto followed down the Mediterranean, should he discovered, the importance of their city as a commercial depot would be at an end. He next applied to Portugal with no better success; and next, through his brother Bartholomew, to Henry VII. of England, but with the same unfortunate result. By this time he was reduced to poverty, his means being exhausted in wandering from place to place; and it was during one of these wanderings that a circumstance occurred which turned the tide of his fortunes, and led to the fulfilment of his most anxious hopes. While travelling through Andalusia, in Spain, he called at the convent of La Rabida to beg food for his child, and by chance explained his views to the guardian or superior, Juan Perez Marchena, who was so struck with their grandeur and probability, that he warmly invited him to remain for some time at the convent, and ultimately gave him a letter of introduction to Fernando de Talavera, the confessor of Queen Isabella. Fernando pleaded the cause of Columbus so strongly, by representing to his royal mistress that by acceding to the wishes of the navigator she would contribute vastly to the extension of the Christian faith, that Isabella agreed to aid his schemes on condition that Columbus should plant the *cross* on the first land he should discover. After many delays, Ferdinand and Isabella signed the stipulations, and Columbus at length set sail, with three vessels and 120 men, on Friday, the 3d August, 1492.

After a tedious and anxious voyage westward, Columbus reached land on the 12th October; and with tears and prayers of thankfulness and joy he kissed the earth, fulfilled his promise to the Queen of Spain by planting the cross in great solemnity, and named the land "San Salvador"—now well known as one of the Bahama islands. Columbus continued his voyage of research, and discovered several other of the West India islands; and, after nearly suffering shipwreck on his homeward voyage, he landed at Palos, on 15th March, 1493. He subsequently made three voyages across the Atlantic, and discovered a number of islands which we need not enumerate, as well as part of the coast of South America; but, although he mistook some parts of the land for Cipango (Japan), of course he failed to discover his anxiously sought-for passage to the East Indies—a route which has been absurdly sought for through impenetrable fields and mountains of ice, with the loss of many a gallant sailor, even in this age of boasted enlightenment and knowledge. On the arrival of Columbus in Spain, after his last voyage in 1504, he found, to his inexpressible grief and disappointment, that his kind patroness, Queen Isabella, had died; and after suffering many mortifications from poverty and neglect, he died at Valladolid, in 1506, "unhonoured and unsung."

The case of Columbus was like that of many of the benefactors of their species, who, instead of being rewarded for their toils, investigations, and discoveries, during their lifetime, are subjected to persecution, poverty, and neglect; and it is only long after their death, when mankind, looking back upon their actions with calmness and impartiality, begin to appreciate the value and importance of their achievements, that tardy justice is done to their memory. Such has ever been, and such will ever be, the way of the world. Whoever is raised, either by fortuitous circumstances, or raises himself by his own talents and abilities to a position above his fellows, must submit to become a target for the shafts of the envy and malignity of those below:—

"He who ascends the mountain-tops, shall find
 The loftiest peaks most wrapt in clouds and snow;
He who surpasses or subdues mankind,
 Must look down on the hate of those below.
Though high above the sun of glory glow,
 And far beneath the earth and ocean spread,
Round him are icy rocks, and loudly blow
 Contending tempests on his naked head,
 And thus reward the toils that to those summits led."—*Byron.*

Columbus was not even awarded the honour of the name of the great continent he discovered. It was called *America*, after Amerigo Vespucci, a Florentine, who entered the service, first of Spain, and afterwards of Portugal; made several voyages to, and discovered some parts of, the South American continent (soon after its first discovery by Columbus); and, having received a liberal education, he was enabled to prepare charts and prescribe routes for vessels in their voyages to the new world, which thus received his name.

Five years after the discovery of America, the Portuguese, being convinced that new and opulent countries would be reached by sailing round the coast of Africa, Vasco de Gama, a man of noble parentage, and endowed with all the mental requisites for a successful navigator—bravery, prudence, and virtue,—was despatched by King Emanuel, with three small ships and sixty men, to prosecute the route followed by Diaz, and to endeavour to double that southern "Cape," which was justly looked upon as opening the portals of the highway to eastern commerce. He set sail on 8th July, 1492; and, having encountered the most fearful tempests, and combated the mutinous opposition of his crew, he doubled the "Cape of Good Hope" on the 19th of November. He then sailed along the eastern coast of Africa, reached the shores of Mozambique about the beginning of March, and, after various adventures, he came to anchor before the African town of Melinda on 30th April, 1493. Here he found some Christian merchants from India, and a pilot from Gujerat; under the skilful guidance of the latter, he reached the coast of Malabar in twenty-three days, and landed at Calicut, a town of considerable mercantile importance, then chiefly in the hands of the Moors. After heroically risking his life in the cause in which he was engaged, by trusting himself in the hands of hostile strangers, and escaping their snares, he pursued his homeward course, and arrived at Lisbon in September, 1499. By the voyage of Vasco de Gama, the commercial traffic with the east was diverted into a new channel. For 1400 years, the route to India from Europe had been through the Mediterranean and down the Persian Gulf, or Red Sea. This old route became totally neglected for the new one by sea, and to this cause may be mainly attributed the decline of some flourishing cities in Italy, Asia Minor, and Egpyt, particularly the trading republics of Venice and Genoa.

In 1500, Pedro Alvares de Cabral was despatched with a fleet on a second expedition to India, for the purpose of settling a colony at Calicut; and on sailing to the south-west, after passing the Cape Verd Islands, he was driven westward by the equatorial current, and accidentaly discovered Brazil in South America. He transmitted an account of his discovery to the King of Portugal, and continued his voyage to India.

In 1496, Henry VII. of England, smarting under the disgrace of having refused assistance to Columbus, readily entered into arrangements with Giovanni Gaboto (*Anglicized*, Cabot), a Venetian, who had settled at Bristol, to undertake an expedition of discovery to the Western Continent, in company with his son Sebastian. They saw North America, for the first time, on 24th June, 1497, and explored a long line of the coast. Sebastian Cabot made many subsequent voyages to America; and, first, under the patronage of the King of England, and afterwards under that of Charles V. of Spain, he discovered Labrador, Hudson's Bay, La Plata, and several other places in North and South America.

It is not a little remarkable, that while the most ardent spirit of discovery and colonization pervaded every other nation in Europe, England stood quiescent in the background; for upwards of one hundred years after America was first visited by Cabot, not a single Englishman had settled in the New World.

The Spaniards, not satisfied with the discovery of a continent, in the attempt to find a nearer route to India, despatched Fernando Magalhaens, in 1520, to continue the search. He passed the southern extremity of America by the strait which still bears his name, and, prosecuting his voyage westward, he discovered the Ladrones, and also the

Philippine Islands, where he was killed in a skirmish with the natives in 1521. His companions, however, continued their course to the west, touched at the Moluccas, and returned home by the Cape of Good Hope, thus circumnavigating the globe for the first time,—a feat which they accomplished in 1124 days.

About the beginning of the 16th century, a zeal for adventure and discovery began also to be exhibited by the French nation. In 1508, Aubert, a Frenchman, discovered the River St. Lawrence. In 1524, Giovanni Verazzano, an Italian, was despatched by Francis I., with a fleet, on a voyage of exploration; he surveyed 700 leagues of the east coast of North America, comprising the whole of the United States. In 1534, the French also circumnavigated Newfoundland, sailed up the River St. Lawrence, and discovered the Canadas; while the Spaniards took possession of the kingdoms of Mexico and Peru, discovered California, and penetrated as far north on the western coast as Oregon, or the Columbia River.

Few other discoveries of importance occurred in the 16th century, unless we agree with the opinion of some, who affirm that Australia was discovered in 1527, by Menezes, a Portuguese navigator; and with others, who hold that Sir Francis Drake, an Englishman, an eminent navigator and commander, also made some discoveries towards the end of this century;—it being well ascertained that Australia was not discovered till 1606, by a Dutchman, and too well known to be concealed, that Sir Francis Drake was nothing less than a "pirate," secretly licensed by Queen Elizabeth, to follow the track of the Spanish discoveries and ships, to rob their towns and vessels of their treasures, and to have free access to return with his plunder and booty to England.

To trace the progress of discovery after the beginning of the 17th century, when English navigators began to take a prominent place in nautical affairs, would be to give a summary of the voyages and travels of Cook, Flinders, Park, Hudson, Vancouver, Anson, Byron, Mackenzie, Parry, Scoresby, and many others, including French, Spanish, Portuguese, Dutch, and Danish navigators and travellers,—to the writings of whom, or to the "Journal of the Royal Geographical Society," we must refer the reader for an account of their various discoveries.

## COAL FIELDS OF GREAT BRITAIN.

### CHAPTER VI.

MID-LOTHIAN COAL FIELD.—MIDDLE SERIES.

(*Concluded from page* 409.)

26. *Limestone.*—In the former part of this article we described the upper or newer portion of stratification of this important district, and enumerated no less than twenty-five seams of coal as overlying the first, or upper limestone of Calcoats. This limestone is of marine origin, and is of a bluish or grayish colour. It is seen on the shore at Joppa, with above 600 feet of stratification interposed between it and the thin seam of coal, No. 25, formerly mentioned. Here, as also at Magdalen-pans, Gilmerton, it measures three feet thick. Its distance from the lowest upper coal at Magdalen-pans is 450 feet, and at Gilmerton, only 246 feet.

The want of limestone and marine remains, in the upper series, seems to justify us in concluding that this series is contemporaneous with the upper coal series of the Lanarkshire basin; and the occurrence of three marine limestones in the central portion of each, with an extensive coal formation underneath, apparently justifies the conclusion. The number and conditions of the coal-beds of each differ, but the analogies are so striking as to leave no doubt on our mind of the contemporaneousness of deposition, notwithstanding the belief expressed by Mr Bald, and assented to by Mr M'Laren, of the upper, or flat coal, having been deposited after the under or edge coal had been tilted into its present inclined position,—an opinion of which no sufficient evidence is afforded. It is very much to be regretted that due attention has not been paid to the organic remains of this portion of the system, as by these the analogy, which we suppose to exist between the eastern and western deposits of the great coal field of the Scottish Lowlands, would, we doubt not, be completely established. The *Roslin*, or upper series, bears much resemblance in its lithological structure to the upper portion of the coal series of Lanarkshire,—both contain red sandstone, and the principal difference is, that the red sandstones of the west country do not contain so much coal as those of the east.

27. *Coal.*—This is a thin seam seventeen inches thick, occurring at Joppa shore, 24 fathoms 4 feet below the Calcoats limestone. The distance, however, at Gilmerton, is only 3½ fathoms. The thickness is nearly the same, but in New Mills level it is two feet five inches. It is needless to observe that in the two former situations it is too thin to be workable with profit.

28. *Coal.*—This coal is also too thin to be workable to advantage; at New Mills level it is twenty inches thick, but at Joppa, Magdalen-pans, and Gilmerton, it is not more than six inches. The distance at New Mills and Joppa is from twelve to thirteen fathoms, but at Gilmerton and Magdalen-pans, it is from twenty-five to twenty-six fathoms.

29. *Allan's Coal.*—At Bryant's and Joppa, this is a two feet seam, but at New Mills and Magdalen-pans, it is only six inches thick. At Gilmerton it is fourteen inches, and lies six fathoms four feet below No. 28. At Joppa, Magdalen-pans, and New Mills level, the distance is from three to four-and-a-half fathoms. At Bryant's, the distance of this seam from the Calcoats limestone is ninety-one fathoms.

30. *Coal.*—This is a very thin seam, never measuring more than fourteen inches thick, and only six inches at Joppa, where it occurs nine feet below No. 29. The distance at Magdalen-pans and New Mills level is four-and-a-half and five fathoms.

31. *Coal.*—This is only known at Joppa, and is six inches thick; it occurs about eleven fathoms above the second limestone, which lies above a hundred fathoms below that of Calcoats.

Here we have a stratification of more than a hundred fathoms interposed between the two upper limestones, containing only five insignificant seams of coal. A similar paucity of coal is met with in the equivalent portion of the Glasgow basin, and the other deposits are not so numerous;—the distance between the upper and the second limestone being only about thirty fathoms, and the coal seams only three in number.

32. *2d Limestone.*—This limestone is of nearly the same quality as the former. It varies in thickness from two to three feet. At Gilmerton, it lies about twenty-nine fathoms below Allan's coal (No. 29); and at New Mills level, eighteen fathoms below No. 30. At Joppa and Gilmerton, it is three feet; but at Dryden, New Mills level, and Magdalen-pans, only two feet thick.

33. *Coal.*—The first seam of coal, underlying the 2d limestone, is called the wood or splint coal. It is wrought in several places; at Gilmerton it is five feet thick; but it only measures about three feet at Joppa, Duddingston, Niddry, Loanhead, and Bryant's. At Arniston, it is reduced to three inches; at New Mills level, it is one foot nine inches thick. The distance from the 2d limestone is from ten to twelve fathoms.

34. *Coal.*—This seam is said to lie about eighty-four fathoms below No. 33, at Duddingston, where, as at Niddry, it is two feet four inches thick. At New Mills, the distance is only thirty-three fathoms two feet, and the thickness is eight feet. The other distances are exceedingly various, but the thickness is generally about three feet. It occurs at the following collieries, Niddry, Gilmerton, Cowden, Loanhead, New Mills level, Bryant's, Arniston. It is the upper coal at Cowden.

35. *3d Limestone.*—This limestone, like the others of the group, generally varies from two to three feet in thickness, the only exceptions being at New Mills level, where it is four and a half feet, and at Walliford one foot, eight inches. The distance from No. 24 varies from seventeen to twenty-four fathoms. It is met with in these conditions at New Eldin pit, Gilmerton, Loanhead, Preston-Grange, Walliford, New Mills level, Bryant's, Arniston, and Stobhill.

These three limestones, with their associated strata of sandstone,

shale, &c., constitute what may be termed the upper marine limestone series. The number of limestones is the same, and the extent of the stratification contained between the upper and lower beds, differs so little from the same series in the Lanarkshire field, that the aqueous conditions appear during the time of deposit to have been nearly the same;—the principal difference in this as in the other divisions, being the greater quantity of carboniferous matter in the Mid-Lothian basin, from whence we may infer a considerable dissimilarity in the extent of the vegetable products of the land.

That coal was derived chiefly from land plants, or plants which grew in marshy situations, is abundantly evident from the remains of plants contained in the imperfectly formed coal, which usually occurs in the lower and upper divisions of a coal bed; but whether these plants vegetated on the spot where the coal derived from them is found, is a problem which geologists appear not yet to have completely solved. This is a subject into which, however, our limits in these descriptive essays will not allow us to enter,—we shall therefore treat of it separately in our geological department, when we come to speak of the carboniferous formation in general.

### Under-Coal Series

36. *Coal.*—This bed is called Baxter's coal at Gilmerton, where it measures two feet in thickness, and lies about three fathoms below the 3d limestone. At other places the distance varies from three to six and a-half fathoms. At Woolmet and Niddry, the thickness is three feet, but two feet may be considered as the usual measurement; at Cowden, however, it is only six inches; and at Stobhill thirteen inches thick. At Preston pit, where it is the upper coal, the thickness is ten inches only. It occurs at all the following places:—Duddingston over Brunstein, Niddry, Gilmerton, Cowden, Loanhead, Woolmet, Walliford, Bryants, Arniston, Stobhill, Preston pit.

37. *Coal.*—This coal lies often about four fathoms below No. 36; but at Bryants the distance is five fathoms; at Preston-Grange it is 12 fathoms. It occurs in the same collieries as No. 36. At Loanhead it is five feet thick; at Niddry and Woolmet, three feet; and in the other places generally about two and a-half feet.

38. *Coal.*—The distance between this coal and No. 37 varies from two and a half to fourteen and a half fathoms. The latter distance, however, occurs at Niddry only; in other places it never exceeds five fathoms. At Niddry and Dryden it is three feet thick; at Cowden and New Mills Level two feet and a quarter; and at other localities, two feet and under. At Arniston it is only six inches. It occurs near the surface at the Sandy quarry of Tranent, where it measures eighteen inches.

39. *Coal.*—This coal varies in its distance from the seam immediately above it, from one to eight fathoms, and the thickness varies from one to three feet. It attains the latter thickness, however, at Cowden, Loanhead, and Bryants. At New Mills Level it is two and a-half feet; and at Niddry, Woolmet, Arniston, and Blinkbonny, two feet; at Gilmerton one foot four inches; and at Duddingston only twelve inches.

40. *Coal.*—This is called the *Great Seam.* Its distance from No. 39, at Bryants, and Cowden, is ten fathoms; in other places it is much less. The following are the places where its thickness is ascertained:—Gilmerton, West Windy-gowl, and Elphinston, ten feet. East Windy-gowl, (twenty inch stone). Sandy Quarry at Tranent, Walliford Cowden, nine to ten feet. Niddry Cowden, Woolmet, Drum, Loanhead, Preston-Grange, Bryants, New Mills level, Preston pit, eight to nine feet. Joppa, Cowsland, Stobhill, seven to eight feet. Bryants and Blinkbonny, six to seven feet; and at Vogrie, four feet only.

This is one of the most important coal-beds in the series; and, extending over a great extent of country, exhibits in a very striking manner the great mineral wealth of the district. Its almost universal thickness tends to reuder it a very important point in the stratification, for determining what coal-beds may be expected beneath it.

41. *The Parrot Coal.*—This is a thin seam of parrot or cannel coal, measuring from a foot to eighteen inches, and lying from fourteen to twenty feet below the *Great Seam* at Gilmerton and New Mills.

42 *Coal.*—At Gilmerton, Drum, Woolmet, and Niddry, this seam is known by the name of the *Stairhead* coal. At Tranent, and many other places, it is called the splint coal. It occurs at all the places enumerated in No. 40. At Tranent, Windy-gowl, Wallisford, Elphinston, and Blindwells, it is from five to six feet thick; at Niddry, Woolmet, and Drum, it is four and a-half feet; at Loanhead, Dryden, and Carberry, three and three and a-half feet; at Cowden, Vogrie, Arniston, Blinkbouny, it measures from two to three feet.

The distance varies from six to fourteen fathoms.

43.—This, like No. 42, is known by different names, such as the *Great Gillespie, Charlie,* and *Parrot.* The distance from the seam above it varies greatly, the least being nine feet, and the greatest eleven fathoms.

At Niddry, Drum, Cowden, and Stobhill, it is about four feet. At Woolmet, New Mills level, and Bryants, it is from three to four feet; at Loanhead, Dryden, and Carberry, it is two feet; Elphinston two and a-half feet; at Tranent, Blindwells, and Pencaitland, it is less than two feet; at Pencaitland it is only one foot, and forms the upper coal.

44. *Moffat's Coal* is the next seam in the descending scale. It averages about three feet in thickness, and the distance is from sixteen feet, to six and a-half fathoms.

45. *Coal.*—This is known by the name of *Gillespie's*, the four feet, the *Small*, and the *Blackbird* coal. It varies from two to five feet in thickness, and is situated from two to eight fathoms below No. 44.

At Gilmerton it is five feet nine inches in one pit, (*Marshall's,*) and in Ainslie's only one foot thick; at Sandy Quarry, it is five feet four inches; at Niddry and Cowden, it measures four feet; and from three to four feet at Woodhall, Loanhead, Dryden, Elphinston, Pencaitland, and Huntlaw. At Penstone the upper coal is five feet thick.

46. This coal lies from two to six or eight fathoms below the last mentioned. At Loanhead it is five feet thick, but in other localities it is only one foot, or less.

47. *Coal.*—This seam is known at different places by the following names:—*Black Chapelhill, Upper Coal, Peattie, Chapel,* and *Carnation.* The distance varies from four to ten or twelve fathoms. At Niddry, it is twelve feet thick; at Gilmerton, three feet three, and seven feet; at Loanhead and Dryden, five feet; at Stobhill, four and a-half feet; at Bryants, four feet; Preston-Grange and Blinkbonny, three and a-half feet; and at Brunstain Muir, two and a-half feet.

48. *Coal.*—This coal lies at eight, three, and one fathom below No. 47. At Niddry, it is three feet; at Gilmerton, two feet nine inches, and two feet two inches; at Loanhead, two feet two inches; at Preston-Grange, twenty inches; and at Stobhill and Brunstain Muir, it is only twelve and fifteen inches thick.

49. *Coal,* known by the name of *Little Gillespie, Lower Coal, Peattie,* and *MacGechie's.* At Stobhill, it is three feet three inches thick; at Niddry, two feet seven inches; at Woolmet, two feet; and at Preston-Grange eighteen inches.

50. *Coal.*—The *Corbie Craig,* or *Kettle purse* coal, lies about five or six fathoms below No. 49. At Duddingston, it is five feet thick; at Niddry, five and three feet; at Bryauts, Loanhead, Woolmet, and Stobhill, three feet; at Gilmerton, two feet two inches; and at Preston-Grange, two and a half feet.

51. *Coal.*—Called the *Stinkie, Peacock,* or *Diamond* coal. It lies from ten to nineteen or twenty fathoms lower than No. 50. At Loanhead and Dryden, it is five feet thick; at Gilmerton, four feet; at Woolmet, three feet; at Duddingston, Niddry, and Glencorse, two feet nine inches; at Fuffet, two feet four inches; and Arniston sixteen inches.

52. *Coal.*—This seam is known by the name of the *Little Splint, Rough,* or *Smithy* coal. At Sandy Quarry, it is four feet eight inches thick; at Elphinston, four feet four inches; Woolmet, three and four feet; Cowsland, four feet; at Niddry, Loanhead, and Dryden, three feet; Fordel, two feet eight inches; Fugget, two feet four inches; and at other places it is eighteen inches or less. It is three or four fathoms below No. 51.

53. *Glass Coal.*—This seam lies about from two and a half to four and a half fathoms below No. 52. At Loanhead, it is three feet; at Dryden, three and a half feet; and Prestou-Grange and Arniston, one and a half feet thick.

54. *Brown's Coal.*—This seam occurs five or six fathoms below the glass coal. At Loanhead and Dryden, where it measures two and a half feet in thickness; at Niddry and Gilmerton, it is only two feet; while at Brunstain Muir, the thickness is only eight and twelve inches.

55. *Coal.*—This is a very important coal, and lies at a very short distance below Brown's coal. It measures from four to

five feet. At Duddingston, Niddry, Langlan Quarry, Loanhead, Blinkbonny, Dryden, and Preston-Grange, five and a-half feet; at Arniston, Woolmet, Gilmerton, Cowsland, three and a-half feet; and from two to three feet at Drum, Fountainhall, Fuffet, Cockenzie, Pencaitland, Huntlaw, and Prestonhall.

56. *Hopes Coal.*—This seam lies from one and a-half to six fathoms below No, 55, and is seldom thicker than two feet.

57. *Coal.*—The *Buttery, Day*, or *Glass Seam*, occurs from three feet to five or six fathoms below Hopes coal; it is generally from three to four feet thick; but at Fordel, it measures six feet three inches; while at Fountainhall and Dryden, it is only two feet, or twenty-two inches.

58. *Corby Craig Coal.*—This seam is known also by the name of the *real Corby*, and *lively Coal.* The distances are various as well as the thicknesses. It is generally a good, thick, workable coal. At Loanhead, Dryden, and Arniston, it is eight feet thick; at Niddry, four feet six inches; Preston-Grange, seven feet seven inches; Brunstain Muir, six feet; Gilmerton and La Mancha, five feet; Woolmet, seven feet seven inches; and at Bryants, three feet. The mean distance is about four fathoms from No. 57.

59. *Coal.*—The terms *Andrew's, Little Rough, Carlton*, and *Peacock's Coal*, are used to designate the seams in its different localities. It measures from four to five feet; at Duddingston, Drum, Gilmerton, Loanhead, and Dryden; at Bryants, it is three and a-half feet, and two and a-half feet; at Arniston, and at Blinkbonny, it is only twenty-two inches.

60. *Coal.*—This is a thin seam, measuring two feet at Niddry, and only eighteen inches elsewhere; it is four fathoms below No. 59. at Loanhead, and four and a-half at Dryden.

61. *Coal.*—The *real Carlton*. At Dryden, this coal lies two and a-half fathoms below No. 60. Here, as at Loanhead, Gilmerton, Woolmet, and Niddry, it is five feet thick; three and a-half feet is its lowest measurement.

62. *Little Splint Coal.*—This lies about nine feet below the *real Carlton* coal. At Dryden, it measures three feet two inches, but in other places it is only eighteen inches thick.

63. *Coal.*—The *Blue North* or *Peddie's Coal.* At Gilmerton this seam lies thirteen fathoms below No. 61; and at eight fathoms at Niddry; at Gilmerton, it is three and seven feet thick; at Loanhead, four and a half feet; and at Niddry and Cranston, two and a half feet; at Dryden, the distance from No. 62 is two and a half fathoms.

64. *Coal.*—*Rough* or *Joppa.* This seam occurs from three and a-half to five fathoms below No. 63. At Niddry, it is four feet thick; but at Gilmerton, it is only one foot two inches, as is the case also in Bald's pit at Niddry. It is two feet thick at Woolmet.

UNDER-LIMESTONE SERIES.

65. *4th Limestone.*—This stratum measures four and a-half feet at Easter Duddingston; and six feet at Gilmerton; it is situated at a distance of ten fathoms below the last mentioned coal.

66. *Coal.*—Diamond *Vexam*, or *Peattie Coal.* This coal lies between the 4th or uppermost under-limestone, in a stratification of about forty fathoms, and another limestone of similar thickness. The coal is from two to three feet in thickness.

67. *Limestone* which measures six feet at Gilmerton, and four at Glencorse, and at Carlow twenty feet.

68. *Coal.*—This coal is four fathoms below No. 67. At Gilmerton, it is one foot eight inches; at Fordel, two feet three inches; at Dryden, four feet two inches; at Fordel, it is seventeen fathoms below No. 57; and at Dryden, two fathoms below No. 66.

69. *Coal.*—The North Green's coal measures commonly from four to five feet thick. It lies about fifty-seven fathoms below the upper under-limestone, No. 65., and eight fathoms below No. 68, at Gilmerton. This coal occurs thickest at Easter Duddington, Niddry, Drum, Gilmerton, Cranston, and Loanhead, where it is from four to five feet. At Bryants, it is three feet three inches, and at Middleton, Fuffet, Eyehead, Blinkbonny, about two feet.

70. *Limestone.*—This bed has been wrought to the depth of twenty-seven feet at Gilmerton. It is of grayish colour, and contains many marine remains, among which the Crinoideæ, or lily-shaped animals are very abundant, together with those of the Spirifer, Strophomenus, and Productus. Its distance, according to Mr Milne, from the North Green's coal, is thirty-one fathoms at Gilmerton, and fifteen fathoms at Niddry. The thickness of the post is exceedingly variable, measuring from four-and-a-half to fifty feet. It occurs at the following places. The figures appended give the thickness in feet.

Earthfield, 7½; Lawfield, 16; Mordun, 5½; Niddry, 4½; Gilmerton, 27; Fullerton, 18; Whitefield, near New Linton, 9; Belston Barn, 6; Crichton-Dean 20; Dosic, 12; Glencairn, 50; Cowsland, 12; Carlops, 10; Middleton, 18; Dryden, 14; Arniston, 30; Edgehead, 18; Blinkbonny, 15 feet.

71. *Coal.*—This is an eighteen inch or two feet coal immediately underlying the above limestone at Gilmerton and Mordun, and other places; beneath which, but at what distance we are not prepared to say, there is another thin stratum of coal seen at the east gate of Duddingston and Langlan House. It is only ten inches thick, and is the lowest stratum of coal known in the formation, with the exception of an eight inch seam which lies about nine feet below the celebrated limestone of Burdie House.

72. *6th Burdie-House*, or *Limestone.*—This stratum, which is about twenty-seven feet thick, and consists of laminated beds of a dark-gray, bluish, or dark-brown, colours have attracted much attention on account of the abundance and stature of its organic remains. There are of those the Megalichthys, Gyracanthus, and other fishes which we have noticed as occurring abundantly in the upper portion of the coal formation of Lanarkshire, particularly in the Blackband ironstones. They occur with plants also common to the same formation; but as these are detached from the whole vertical section of the western coal field, their occurrence in the Burdie-House limestone is not so remarkable as that of fishes, which, if the coal-fields of Lothian and Lanarkshire are of contemporaneous origin, must have propagated their species during the deposition of more than a thousand fathoms of strata, and the accumulation of nearly two hundred feet of vegetable coal. Our limits forbid us to enter into this most interesting subject at present; so we must defer its consideration to another paper.

## THE CELEBRATED PRUSSIAN NEEDLE-GUN.

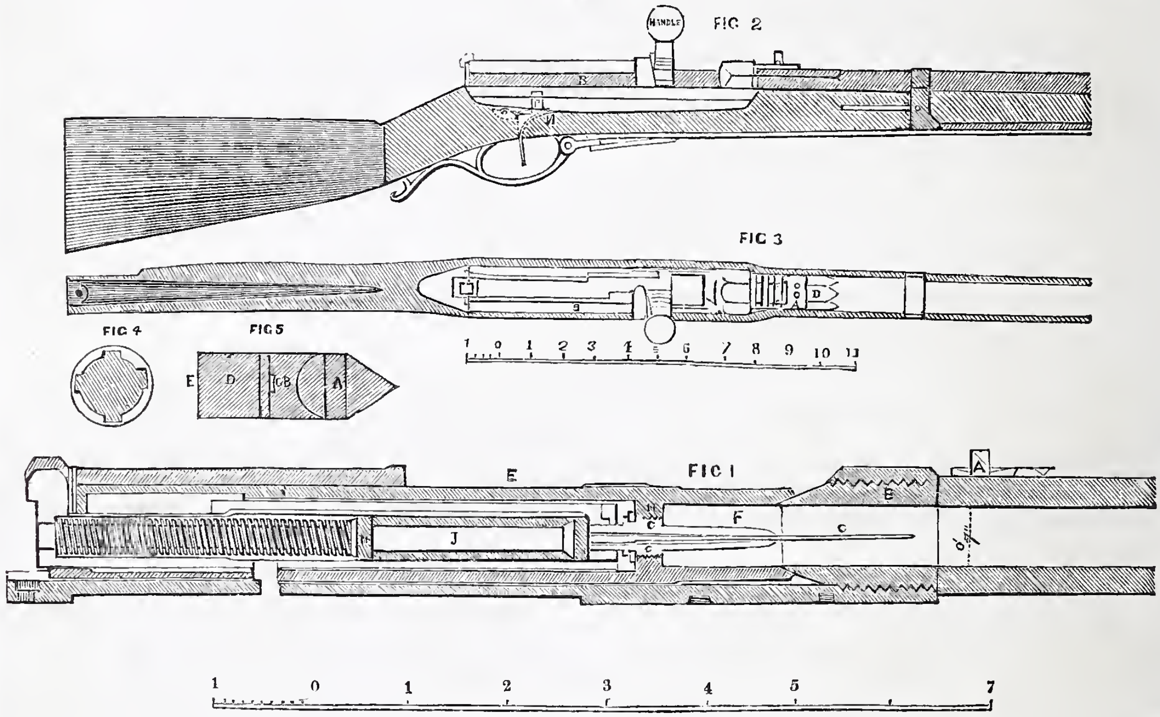
WHILE the cry of a respectable class in this country is "Peace, peace," there seems to be a general curiosity, and even a mania, existing on the subject of fire-arms. In the prospect of aggression from abroad, the Minié or Delvigne rifle has obtained an unwonted popularity for some months, and even amid the peaceful splendour of the Crystal Palace—amid the trophies of peace and the triumphs of manufacturing skill, revolving pistols, improved rifles, and other terrible messengers of death, breathing only of battle and slaughter, occupied their silent niches in that temple of industry. This may at first sight appear a strange anomaly, if not a gross inconsistency; and yet there are those who imagine, with some show of plausibility, that art, in its peaceful but resistless march, will ultimately put an end to war, by rendering the cause of right impregnable, by putting into the hands of every man and nation the means of defending themselves against all aggressors, and so equalizing the chances of success between the weak and the strong, that all the world, dreading mutual destruction, will be glad to sit down and live at peace with each other.

These remarks have been suggested, not so much by the nature of that particular fire-arm which we are about to describe, as by a consideration of the great amount of ingenuity exercised in the present day in devising improved means of destruction—a species of ingenuity of which the Prussian needle-gun is certainly no mean proof. To an English reader, its name—the Zundnadelgewehr—is somewhat formidable-looking; but, after all, there is nothing so alarming in the title, when we term it, what it really is, the needle-igniting musket: that is to say, the explosion is produced by the passage of a needle or thin steel-wire through a fulminating compound contiguous to the charge of powder. The mechanism connected with this needle is certainly the greatest novelty, although, perhaps, not the greatest improvement or recommendation, exhibited in the Zundnadelgewehr. It may be described as

combining the use of percussion with that of a particular kind of ball, which, being conical at the point, cylindrical at the centre, and round at the larger end, is, like the ball of the French rifle, considerably heavier than a sphere of the same calibre. It becomes rifled in passing through the barrel, and is propelled with considerably greater force than the ordinary rifle-ball, owing to two causes—a suitable centre of gravity, and the more perfect ignition of the powder. The latter of these advantages arises from the fact, that the ignition takes place in front, instead of being, as formerly, at the other end of the charge—an improvement accomplished by means of the metal needle above mentioned. This needle is forced by a spiral spring clean through the charge, till it reaches the fulminating powder, which forms part of the cartridge, and is placed on the other or outer side of the charge. The advantage of igniting the charge in front, is considered one of the greatest belonging to the improvement. This and the other points of difference between the Zundnadelgewehr and the ordinary musket, will be best understood by referring to the annexed engravings.

Figs. 1, 2, 3, exhibit the interior and exterior mechanism. The interior parts are displayed in fig. 1; fig. 2 is a side view of the lock exteriorly; and fig. 3 is a view of the upper part, with the trigger turned away from the eye. Fig. 4 is a section of the interior of the barrel, and fig. 5 is the cartridge. Scales of inches are annexed, and the letters of reference correspond in figs. 1, 2, 3.

To render our description of the mechanism more intelligible, we may begin by explaining the peculiarities of the cartridge, fig. 5. It is a cylinder, of uniform thickness, terminated by the pointed cone of the ball. The envelope is of thin, but strong paper. A is the ball, B the paper bottom or wadding in which it is embedded, and D the powder. The end at E is formed like the rest, of a single thickness of paper, through which the needle is forced by a spiral spring, penetrating the powder, D, till it reaches the priming composition, which is placed at *c*, in an indentation in the paper bottom, B. On penetrating this composition, it ignites, and consequently, as already stated, the charge is lighted in front instead of at the other extremity, as usual. The advantages of this will be more apparent when we describe the interior construction of the barrel, where the cartridge is deposited.




The barrel is 34 inches long, and is rifled, as shown in fig. 4, with four grooves, which take one turn and a quarter in the length. It has a high back-sight, A. B is the strong open guider or socket into which the barrel is screwed. C is the steel needle; and the chamber, properly so called, is bored out in a slight degree conically from behind *c*, so that, when the cartridge is placed in it, the shoulder of the ball (A, fig. 5) meets, and is stopped by the projections of the ribs of the rifling. It will be observed that this shoulder is shaped for that purpose, while the body of the ball is of sufficient diameter to fill the full depth of the grooves. E is an iron tube sliding inside the guider, with a strong helve or handle attached to it, exhibited in figs. 2, 3. This tube has a space, F, at the front end, next the barrel, of about $1\frac{1}{2}$ inch in length; and in the middle of this space is the needle-conductor, G, which is pierced longitudinally by a small hole, through which the needle passes to penetrate and ignite the charge. This guide, G, is screwed from behind into a solid plate of iron left in the tube, H. and it is this plate which, like the breech pin-piece of the ordinary musket, receives the whole reactionary force of the charge. Again, behind this plate there is another tube of iron, S, having a spring with double catch attached, and carrying within it an inner small tube, J, extending to the left extremity of the sketch (fig. 1). On one half of this small tube, J, are two projecting rings, and in the other half of its length is a spiral spring, K. Through this tube, also, passes the needle, which is a thin steel-wire, pointed at the penetrating extremity, and screwed at the other end into a brass head, which again screws into the interior tube that carries the spiral spring. The trigger is of a peculiar form, with a straight spring, having two knuckle movements acting upon a ball: the first movement fires the gun, and the second is applied when the whole mechanism is to be taken out and cleaned. There are no pins whatever, and no screw, except that by which the needle is connected with the inner tube, and this is never disturbed except when the needle has to be replaced by a new one. By a simple reverse movement of the trigger, the whole of the mechanism is taken out behind, and the parts can all be taken to pieces, cleaned, and put together again by a soldier in two minutes.

The progress of this musket in Prussia was at first slow; but, after the fusiliers were armed with it, it came to be generally adopted, and, it is believed, will probably soon be used throughout the Prussian army. The igniting of the charge in

front, and the small vacant space left behind the cartridge, are undoubted advantages; and to these two circumstances the Prussians attribute, not only the additional range arising from the more perfect ignition of the powder, but also the slightness of the recoil. The celerity in firing is great, and is stated to amount, without over-exertion, to about six rounds in a minute. The freedom from windage admits of a range of 800, or, according to some, even 1200 yards; but this is, perhaps, an exaggeration. A ball for the same bore is much larger than that of an ordinary musket; and, being formed by pressure, it is more solid, and has at the same time a more correct position of the centre of gravity. Provision is made against crushing the powder, by the peculiar shape of the ball, which only permits the cartridge to enter to a certain point, and this is a decided advantage. There is little doubt that the ball, being rifled, must be truer in its flight than the ordinary round bullet. The pasteboard wadding, which is a part of the cartridge, assists in clearing the barrel from the effects of the previous discharge; and it is stated to be another advantage, that as the soldier can load almost as easily in a recumbent as in an upright position, he need not, when once behind cover, allow any part of his body to be exposed to the enemy's fire. In conclusion, it may be stated that, as the lock consists chiefly of a spiral spring, communicating motion to the wire, the movement of the trigger is simpler, smoother, and more delicate than that of other muskets, so that there is less to prevent a correct aim and an accurate and deliberate fire.

These are the alleged advantages of the needle-gun. On the other hand, several objections are urged which are worthy of serious consideration; such as the presumed liability of the spring to get out of order, the divergence to the right or left to which the steel needle may be liable in passing through the powder, and the probability of missing fire when the needle gets dirty. Another objection is the escape of gas through the apertures, after firing has been continued for some time; and, lastly, the wear and tear of the barrel, from the smoke and burnt powder issuing through the apertures at the junction of the cylinder with the barrel.

Some of these objections, as, for instance, the diminished power of the spring by constant use, and the divergency to which the needle may be liable, are undoubtedly serious; but it is affirmed, on the other hand, with much reason, that both the spring and needle may be renewed from time to time at a trifling expense; and that, by having a few spare needles and springs, as one of each for eight or ten muskets, or in any other proportion that may be found necessary, little inconvenience would result from a few occasional derangements in this most delicate part of the mechanism. With regard to the liability of the piece to miss fire, and the more serious defect of the escape of gas, it is alleged that (in the latter case, at least) these only take place to any extent after some fifty or eighty discharges, so that a general action might be fought before even the piece required to be cleaned. It must be admitted, however, that the objection of the escape of gas, which is often so great as to remove a small weight placed on the aperture, is worthy of serious consideration, and that it will be necessary to remove it by some contrivance before this Prussian musket can be considered as nearly perfect. No piece yet invented is without some imperfections; and in testing the value of any alleged improvement, the advantages must be carefully weighed against the disadvantages. Even in the common musket, the escape through the vent is considerable; while it is deficient in many of the assumed advantages of the Prussian gun. From various specimens of pieces with absolutely close-fitting breeches shown at the Great Exhibition, it may be presumed that the defect in question will ultimately be overcome entirely.

In the meantime, there is little doubt that, whatever be its defects—and some of them are freely admitted—the new Prussian musket is capable of great execution. It is stated that, in one part of the hard-fought battle of Ilstedt, the Danes found themselves opposed by skirmishers armed with this new musket. The effect is described in the report of the Danish Commander-in-Chief, Krogh:—"The enemy," he says, "under cover of a bridge, fired with pointed balls (spitzkugeln), at a distance of 100 and 150 yards. It was in vain that a couple of guns threw shells at a short range among the skirmishers; it was in vain that a body of cavalry made their several attacks; it was in vain that the endeavour was made to bring up the infantry from Oberstolk, which was now in flames, while a fierce engagement was going on in it from the house-windows and the streets. In less than an hour we suffered a great loss. The brave General Schleppegrell fell, mortally wounded, during the attacks; the chief of his staff, Lieutenant Colonel Bulow, was severely wounded; the commander of the battery, Colonel Baggeilsen, was made prisoner, and two of his guns taken by the enemy. Several other officers were also killed, among them Lieutenant Carstensea, whilst endeavouring to rescue Captain Baggensen, and about 70 subalterns and privates. At least 90 horses were killed or taken."

In conclusion, we may add that, besides a more distant execution claimed for this and other analogous specimens of new fire-arms, the admirers of these, especially of the Prussian pattern, do not hesitate to affirm, that its fire will even be more formidable than that of grape-shot; that the gunners would be picked off at such a distance as to make it impossible for them to serve the guns in face of light infantry, and that it will, in consequence, supersede the use of light artillery. "It is also alleged (says Colonel Chesney, to whose 'Observations on Fire-arms' we have been indebted for the leading details in this article) that personal conflicts, such as line against line, or column against column, will cease altogether, and future battles be decided by the effects of a rapid and destructive fire, in the precision of which, rather than on personal contact and extensive combinations, the result will depend. Since a single man can now be struck down by a musket-ball at a considerable distance, it follows that the means of defending field-works, a river, a defile, or in fact any strong post where the defenders can remain under cover, whilst the attacking force is exposed, will be greatly increased. In such cases, more particularly in that of a fortress, the defence will probably become superior to the attack, at least after such modifications in the construction of fortresses shall have taken place as will give longer lines of defence, protected by a loop-holed musketry fire from those parts of the works which, in this respect, have been hitherto rather neglected."

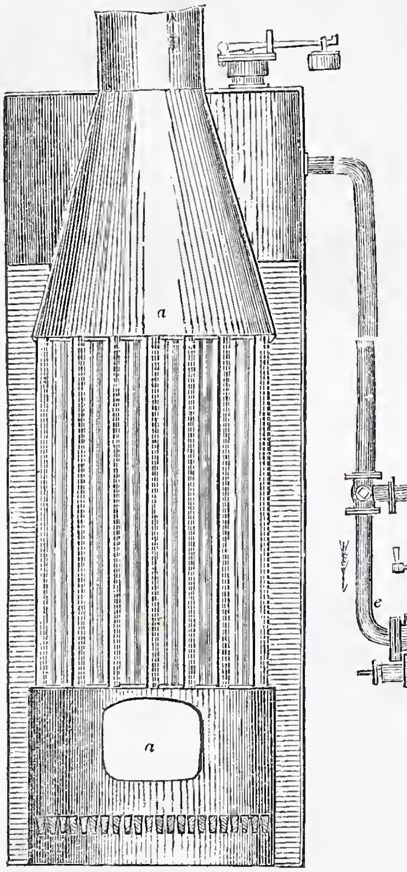
These remarks of the gallant colonel, founded as they are on scientific knowledge, and a thorough acquaintance with the subject, tend to confirm the observations with which we introduced this paper.

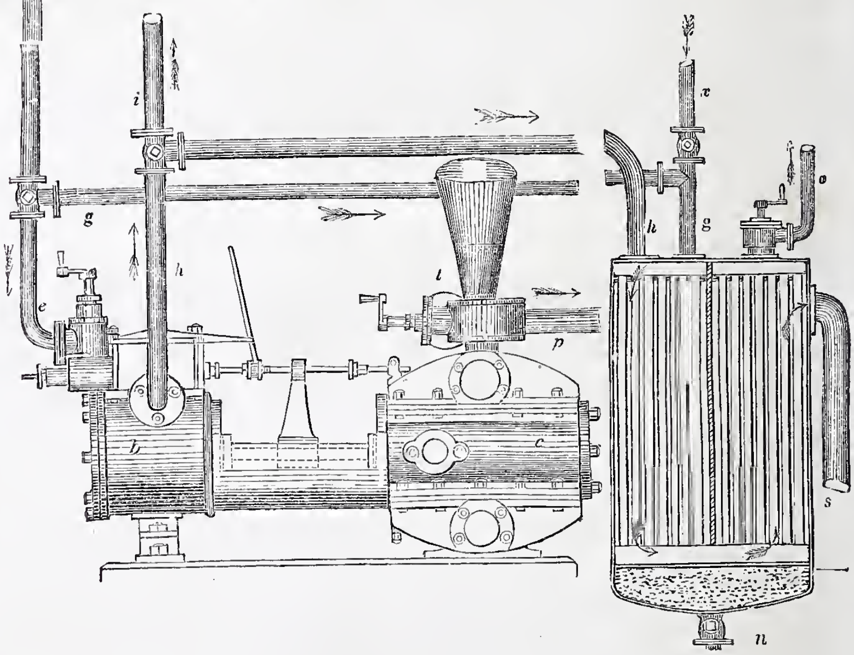
## COPELAND'S FRESH-WATER APPARATUS AND FIRE-ENGINE FOR SHIPS' USE.

This apparatus is the invention of Mr. C. W. Copeland, Chief Engineer, United States' Navy, and has, we believe, been patented by that gentleman in this country. He has applied it with success in the United States' Navy, and we think its advantages are such, that it ought to be generally adopted. In our own and the French navy, an apparatus has been long in use to obtain a supply of fresh water by distillation; but the peculiar and important feature of Mr. Copeland's arrangement is the combination of suitable mechanism for that purpose, with an auxiliary engine for the extinction of fire, or any other necessary operation. The engine may be turned to account in various ways: it may be employed, when in port, to pump out bilge water, or to fill the large boilers of steam-vessels,; but nothing can be more important than its use as a fire-engine, which ought to be a part of the regular furnishing of every large vessel. The dreadful calamity of the *Amazon* might have been in some measure alleviated, if not entirely prevented, had such an engine been in readiness to pour a volume of water on the flames as soon as they were seen to burst forth. Indeed, we may add, that the Report of the Board of Trade strongly insists on the importance of the right application of an auxiliary engine to this purpose. Of the other use of Mr. Copeland's apparatus—the furnishing, at all times, a supply of fresh water when needed—it is quite unnecessary to speak. It is true that, in ordinary circumstances,

water may be shipped at port to last throughout the voyage; but sometimes, even in port, it is difficult to procure fresh water, and accidents frequently occur which cause the supply to run short; so that the owner of a vessel is really without excuse who does not provide the obvious means of rendering his ship independent of accident, as far as concerns the supply of a prime necessary of life. Even in point of economy, the distillation of fresh from salt water on the voyage has this advantage to recommend it, namely, the fact that one pound of coal is often more easily and cheaply procured, and is certainly more easily carried, than seven pounds of water. With these preliminary remarks, we shall proceed to describe Mr. Copeland's apparatus, combining the uses which we have stated.

The engraving represents an elevation, partly in section, of a boiler, steam-engine, pump, and condenser. The whole of this apparatus occupies but a small space, and may be placed on midships.




In the boiler, *a*, *a*, which is of the ordinary vertical construction, the only peculiarity deserving of notice is, that no part of the tubes is left uncovered by the water, and the smoke-box or take-up into the chimney is so constructed as to give a better amount of steam-space than usual. *b*, is the cylinder of the engine; *c*, a double-acting pump; and *d*, the condenser. The steam is conveyed from the boiler to the engine by the steam-pipe, *e*; but when the power of the engine is not required, the steam is led by the branch-pipe, *g g*, directly from the boiler into the condenser, *d*. This last is cylindrical, and is divided, for the greater part of its depth, by a vertical partition. The steam to be condensed passes through the tubes, which are cooled externally by water drawn by the pump, *c*, from the sea. The pump draws the water by the pipe, *r*, and delivers it by the pipe, *p*, into the condenser, where it passes outside the tubes under the partition, as shown by the *dotted* arrows, and finally escapes into the sea by the pipe, *s*. The condensed steam, or distilled water produced, passes through the filter, *m*, by the pipe, *n*, to a tank placed in any suitable part of the ship. Any steam remaining uncondensed escapes through the pipe, *o*.

The exhaust steam from the engine, when in use, is conveyed by the pipe, *h h*, to the condenser, *d*; or, when the distilling apparatus is not required, it may be transmitted to the chimney by the pipe, *i*. When the pump is used as a fire-engine, the water is shut off from the condenser, and pumped by the engine through one or two hoses attached to the flange, *t*. This is the complete arrangement on board sailing vessels. When applied on board steamers, a pipe, *x*, is provided, by means of which steam may be conducted to the condenser from the large boilers, and thus the distilling go on, when required, without getting up steam in the auxiliary boiler. But even in steamers the auxiliary boiler is of great use, by furnishing a ready means of getting up steam in a very short time, and with little trouble and expense, when the large engines are not employed. This is important when the vessel is lying in port, or when, from any cause whatever, the large engines are idle. In that case the auxiliary engine may, as already stated, be employed to pump out bilge-water, to fill the boilers, or to act as a fire-engine. The volume of water thrown by it is very great, and we understand it acts without noise.

It is to be hoped that, if Ericsson's caloric engine succeed, the danger of fire at sea, in steam-vessels, will be very considerably diminished. The principle of this engine is the application of heated air, instead of the expansive power of steam, as an agent for propelling machinery. A large vessel, with an engine on this principle, of which we shall take an early opportunity to give a particular description, is now being fitted up in the United States; and possibly the working of such an engine, by totally dispensing with boilers, and greatly economising fuel, may altogether supersede, in vessels propelled by that agent, the necessity for Mr. Copeland's auxiliary steam apparatus. This, however, is still a comparatively distant prospect, dependent on many contingencies; and meanwhile, in sailing vessels, and more especially in those which are now so extensively employed in the emigrant movement to Australia, we cannot help thinking that Mr. Copeland's apparatus ought to be generally adopted, both for affording a certain supply of water in case of need, and likewise for extinguishing fire, if required for that purpose—a calamity terrible at sea in any circumstances, but in the case of an emigrant vessel, accompanied with indescribable horrors.

# POLITICAL ECONOMY.

## CHAPTER III.

### MONEY.

Dr. Johnson, the great lexicographer, says that money is "any metal coined for traffic." Mr. Huskisson observes, that "it is of the essence of money to possess *intrinsic* value." Lord Liverpool designates it "the coins of the realm." Sir Robert Peel, in the introductory remarks to his exposition of the principles of "the Act of 1844," as it is called, gives the following definition of the term money: "In using the word money, I mean to designate by that word the coin of the realm, and promissory notes payable to bearer on demand;" and in reference to the latter portion of this definition he says, in a subsequent part of the same speech, that "it (paper currency) is the substitute for and representative of coin, and, with coin, constitutes money;" that is, he believes that paper currency constitutes money when based on and is the substitute for coin, which, in principle, is equal to confining money to coin. The previously published opinions of Mr. Lloyd, Mr. Norman, and others, are to the same effect. It may also be mentioned, that, among various nations, a very considerable variety of commodities appears to have been used as instruments of purchase and exchange. For example, at various periods, we find employed as "money," beads in American India, beaver skins among the Krees Indians, cattle and horses in Tartary, blocks of salt in Abyssinia, shells among the islands of the Pacific ocean and in some parts of the interior of Africa, dried fish in Newfoundland, tobacco in Virginia, sugar in the West Indies. In the early stages of Roman history, bars of copper were used as currency. Ancient Sparta employed iron as an instrument of exchange. In ancient, and more especially in modern times, and in commercial countries, gold and silver have to a large extent been adopted as money. Again, some of the most distinguished writers on political economy, both continental and British, it is evident, assume as an axiom, that money is a *commodity*, or an instrument possessing *intrinsic* value, from the fact, that their reasoning on the subject is based on that assumption; and finally, it is almost unnecessary to state, that in the minds, as also in the practice, of the public generally, the nature of money is invariably associated with metallic substances, or, in the language of Mr. Huskisson, already quoted, that "it is of the essence of money to possess *intrinsic* value."

Against this conclusion, however, supported as it is by universal practice, and by the opinions of so many men distinguished for their talents and for their services to society, reasons have been adduced by writers who have rigidly, and with admitted impartiality, concentrated great attention on the subject, and which have of late contributed to shake considerably the faith in the infallibility of the doctrine, that "it is of the essence of money to possess intrinsic value." Of the true definition of money, Mr. John Little of Glasgow, one of the political economists referred to, maintains that unerring nature can alone exhibit the principle upon which only we can be conducted to the realization of a clear apprehension of what money really is and what it is not, and which principle will be found exhibiting itself by the side of the circumstances which gave birth to the original necessity for its employment. In proportion, the same writer observes, as the divisional system of employment made progress in society, the practice of direct barter became surrounded with

a correspondingly increasing amount of physical inconvenience. Thus, the farmer accumulated corn, and he required cloth; the shoemaker accumulated shoes, and he was in want of tea; but the weaver who had cloth to dispose of had no immediate necessity for corn, and the grocer who had tea to sell was sufficiently supplied with shoes, consequently, a direct barter between the farmer and the weaver, and between the shoemaker and the grocer, of their respective productions, could not take place. Hence arose the necessity for a general medium through which the farmer could immediately command the cloth, and the shoemaker the groceries, or any other commodity they might happen respectively to require; in other words, an instrument for which, in the first place, the farmer could exchange his corn, and the shoemaker his shoes, and with which instrument in their hands the same parties could, in the next place, go the whole round of the market, and purchase cloth, tea, coffee, sugar, hats, hosiery, or any other article which their necessities might point out. This instrument has been named money, and, with regard to its nature and functions, it will at once be admitted, that so far as the farmer and the shoemaker are concerned, it is something which, in the general market, takes *the same place* which their corn and their boots and shoes would occupy as instruments of purchase did the money *not exist;* that is to say, when the farmer takes the circuit of the market for the purpose of purchasing cloth, groceries, bread, butcher meat, &c., the instrument of purchase, or the money which he employs for that purpose, is *instead of*, or a *substitute for*, the corn which he originally held for sale. And when the shoemaker makes his appearance as a purchaser at the grocer's, the hatter's, the butcher's, the hosier's, &c., he presents money *instead of* boots and shoes as his instrument of purchase. Were the money annihilated, and barter restored, the corn, the boots, and the shoes, would be employed by the producers *in its stead.* In like manner, the producers of all the other commodities, in employing "money" in their rounds through the general market as purchasers, employ something *instead of*, or as a *substitute for*, their own productions. If no money were employed, these productions themselves would have to take its place in the market; and, on the other hand, were there no productions to be exchanged between man and man, there would be no necessity for money, or for a medium of exchange, because there would be nothing to be exchanged—nothing to pass through that medium. It is indubitable, therefore, says Mr. Little, that money is *representative* in its character; and consequently, that its value is received from the things it represents, and that gold and silver, being themselves commodities, should not only be treated as such, and take their place in the markets of the world with any other form of production, but that their employment as money constitutes the producing cause of nearly all the derangements and fluctuations in the industrial operations of society, because, being a commodity, its price rises and falls in proportion as the demand exceeds or falls short of the supply.

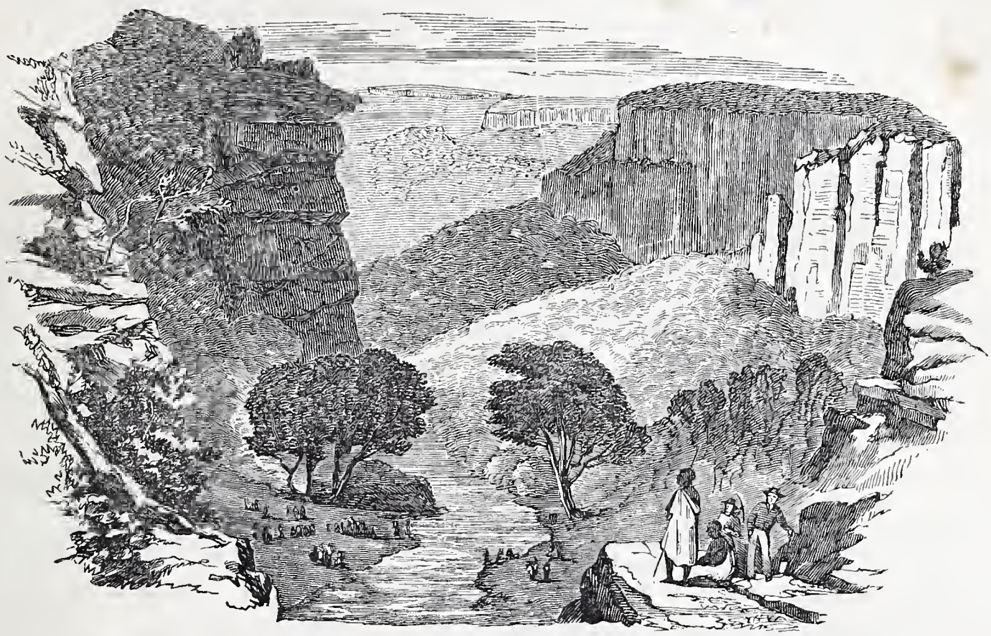
While thus the advocates of a metallic currency on the one hand, and those of a paper circulation based on and representative of value on the other, are standing at bay, each resting with apparent satisfaction on the validity of their respective arguments, independent circumstances have recently occurred which will probably, in the course of a few years, place the dispute practically and for ever at rest—we refer to the late auriferous discoveries in California and South Australia.

The Californian gold mines, or placers, as the gold region is termed by the natives, is divided into two parts, the eastern and the western. The eastern portion, lying between the Rocky Mountains on the east, and the great range of the Sierra Nevada on the west, comprehends an area of about 500 square miles, and, saving the region around the Great Salt Lake in the north-east corner, and a few green spots along the flanks of the Western mountains, presents the appearance of a waste desert of burning cones and bald mountains, and is covered with evidences of volcanic action. It comprehends five-sixths of the territory of California. The Great Basin is surrounded by mountains on all sides, and the rivers which flow into it from the mountains empty into lakes, the waters of which are evaporated in the sun, as a substitute for an outlet to the sea, or the streams are absorbed by the sands of the desert; as, for instance, Mary's River, after a course of 300 miles, suddenly sinks into the sands, its waters being as thick and bitter as bitumen, from the impregnations of its volcanic trail.

The western division of California lies west of the great range of the Sierra Nevada, and between it and the Pacific ocean. Lying at the western base of the Sierra Nevada, are the valleys of the Sacramento and San Joaquin. These valleys are in reality one—a single geographical formation, near 500 miles in length. They are discriminated only by the names of the two rivers, San Joaquin and Sacramento, rising respectively at each of its ends. The gold region of California is in the Sacramento and its tributaries. The climate of the country has no winter in the valley, but the rainy season and the dry, the former beginning in November and ending about the end of February. The rest of the year is without rain; but the various streams from the Sierra Nevada afford all the facilities for irrigation in the heats of July and August. The whole valley abounds in wild cattle, wild horses, elks, deer, antelopes, bears, partridges, &c. All the products of the United States, from apples to oranges, from potatoes to sugar-cane, may be produced in the valley of the San Joaquin and Sacramento.

After the breaking out of the war between Mexico and the United States, this splendid country was taken possession of by the latter, and by a treaty of peace was yielded to them in 1848; and although, so early as 1589, we find in the black-letter volume of Richard Hakluyt, who accompanied Sir Francis Drake's expedition in 1577–79, that (referring to California) "there is no part of earth here to be taken up wherein there is not a reasonable quantitie of gold and silver,"—and although practical evidences of the truth of Mr. Hakluyt's statement were known to continue to present themselves in greater or less abundance to the native Mexicans, it was not till the transference of this region of country from that indolent and semibarbarous race to the possession of the energetic and enterprising Anglo-American nation, that its auriferous treasures assumed the position of a great reality, destined to effect, by its exhumation, a revolution in the commercial operations of the world. The modern discovery of gold in California was made by a Mr. Marshall, who had been employed to build a saw-mill for Captain Sutter, on the banks of a small stream among the hills, which at this point rise about 1000 feet above the level of the Sacramento plain. A dam and race for the mill having been constructed, when the water was let out on the wheel, the tail race was found to be too narrow to permit the water to escape with sufficient rapidity. Mr. Marshall, to save labour, let the water directly into the race with a strong current, so as to wash it wider and deeper. He effected his purpose, and a large bed of mud and gravel was carried to the foot of the race. One day, as Mr. Marshall was walking down the race to this deposit of mud, he observed some glittering particles at its upper edge. He gathered a few, examined them, and became satisfied of their value. He then went to the fort, told Captain Sutter of his discovery, and they agreed to keep it secret until a certain grist-mill of Sutter's was finished. It, however, got out, and spread like magic. In a few weeks hundreds of men were drawn thither, and remarkable success attended their labours. In three months from the discovery of Mr. Marshall, upwards of 4,000 men were working in the gold district, of whom more than one-half were Indians, and from 30,000 to 50,000 dollars worth of gold were obtained daily by the explorers. The gold is now discovered in every possible situation, and in combination with many different qualities of rock and soil. Quicksilver is also extensively used in the process of separating the precious metal from the quartz or granite, which, when crushed, yields an ample recompense for the labour of both operations; and the same agent is brought into play in the case of a deposit of a somewhat peculiar character, which, it has just been

found, is also rich in the glittering grains. This new raw material of the great gold manufacture, is described as soft clay and slate, saturated with gold in small particles and large lumps, and is found embedded in layers at from ten to twelve feet below the surface, apparently the alluvial deposit of an earlier age, the rocks from which it had been washed being then as thickly impregnated as they are still with the auriferous metal. These, as it may be, antediluvian treasures, are now turned up to the eye of man, who, testing the strange deposit, discovers it to be "about one-fourth gold in bulk, and over one-half gold in weight." These proportions are not invariable. One mass yields to the pound three dollars' worth



of gold, another no less than twelve dollars' worth. To the general yield of gold in California, there at present appears to be no limit, every increased application of labour being followed by a corresponding supply of the precious metal. From two to three millions per annum of increase to the commodity which supplies the world with a circulating medium, has already been the result of the Californian discoveries; and instead of any diminution of the amount, every vessel arriving in this country from the auriferous districts, convey the most indubitable evidence of the exhaustless character of the supply.

The Australian discoveries were made by a Mr. E. H. Hargraves, in January, 1851. Having travelled over the Bathurst district about sixteen years before, the scenery, and, to a limited extent, the geological features of the country, made an impression on his mind. Latterly he visited California, and while in the gold regions in that country, was struck by their resemblance to the wilderness which he had seen in Australia so many years before. A resistless desire to return and explore for gold then took possession of him, and, as expressed by himself, "he could not rest until he had satisfied it by a personal search;" which he at length accomplished, although under difficulties and privations—the result being, according to his words, "the disclosure of unbounded wealth" to his fellow-colonists. It is also stated, that the Rev. Mr. Clark, a local geologist, has all along contended that not only was the precious metal to be found in that locality, but throughout the principal chain of mountains which belt the Australian continent. It is added, that for some time past a shepherd, named M'Gregor, had been in the habit of bringing gold to Sydney for sale, who maintained, however, great secrecy respecting whence he gained it. Mr. Hargraves, after traversing the country for about 300 miles, took advantage of his experience in California, and, selecting a spot, proceeded successfully to work. He immediately named the place the "Ophir diggings," and they have since remained in increasingly active operation.

This gold district is described as lying to the westward of Bathurst, the Ophir diggings being 35 miles north-west, on the Sommerville Creek, near its junction with the Macquaire River. Later accounts, recently received in this country, not only announce other auriferous discoveries in new districts of country, but gold in new material at the old regions.

In the Bathurst region, as in the San Franciscan, a sort of brown clay has been discovered to be highly auriferous, while quartz crushing is going on to a great extent—a bridge built with quartz having been actually taken down to have the quartz squeezed out of it; and the inhabitants have further awakened to a sense of the fact, that they have been in the habit of mending their roads with similar precious stones. Here we have Whittington's fancy, about the streets of London being paved with gold, realized in a remote agricultural district in one of our most distant colonies. Near Port Philip, deposits have, it appears, been found even richer than those in the neighbourhood of Sydney. The place is named Buningyong, about eighty miles from Melbourne and fifty from Geelong, and its creeks and rivers are described as teeming with treasure. So rich is the soil in one place, that eight yards square is considered a sufficient allotment to each labourer in this highly profitable "croft system," where an ounce of gold per day is considered an average yield. Cases of extraordinary and almost fabulous success are not unfrequently reported; such as one man making his £1,000, and another his £1,500, in one week, at the trade. Within a period of ten months, the colonies of New South Wales and Victoria have each shipped about one million's worth of gold, or two millions' worth in all. And when it is considered that this has been the result of unskilled mining, of labour untrained to the peculiar employment, untaught by science and unsustained by capital, and that the number of diggers has hitherto borne the most insignificant proportion to the extent and richness of the field, and that every day new regions of auriferous deposit are found in almost every part of the interior, some estimate may be formed of what Australia is destined to achieve on the destinies of the world.

## NATURAL PHILOSOPHY AND CHEMISTRY.

### CHAPTER XVI.

#### ON THE PRESENT STATE OF VOLTAIC ELECTRICITY AND ELECTRO-MAGNETISM.

#### PART I.—VOLTAIC ELECTRICITY.—(*Continued.*)

32.—ASSUMING the reader to be now in a position to form a tolerably clear notion of those arrangements of the elements and molecules of bodies, which lead to the production of electrical and chemical phenomena, we shall direct his attention to those important discoveries of English and foreign philosophers, which, within the last twenty years, have effected so great a change in our views of the nature and mode of action of the electric principle.

33. The important law with which Faraday has enriched the science deserves our earliest notice; for upon it depend some of the most extraordinary discoveries that have been subsequently made in voltaic electricity. It is this,—"that the chemical power is in direct proportion to the quantity of electricity which passes." One of the results of this law has been the development of the definite nature of electro-chemical decomposition—the established principles of which demand at our hands some elucidation.

34. We are informed by analysis, that water is composed of 1 part by weight of hydrogen and 8 of oxygen; and that oxide of zinc consists of 32 parts by weight of zinc, and 8 of oxygen. Now, if we suppose a certain quantity of electricity to be disengaged, and set in motion, by that inherent attractive force, or predominant affinity, which dissevers the connexion between the hydrogen and oxygen in a particle of water, and causes the union of the same proportion of oxygen with 32 parts of zinc; that same quantity of electricity will, in its current state, decompose 9 of water, and no more, by the platinum electrodes, resolving it into 8 of oxygen and 1 of hydrogen; and a similar quantity of electricity passing in succession through fused chlorides of silver and iodide of lead, will, by decomposition, evolve 36 of chlorine and 125 of iodine at one electrode, and 108 of silver and 104 of lead at the other electrode,—these numbers representing the exact proportions in which the respective elements of each substance combine. Consequently, if a measure of water be placed in any part of a voltaic circuit, that quantity of it which is decompounded in a given time, or the quantity of its constituent elements which is evolved in the same time, either in a mixed or separate state, affords a correct measure of the quantity, or velocity, or force, of the electricity which has passed in a similar interval. Messrs Faraday, Poggendorff, De Moleyns, and others, have constructed various instruments for this purpose; some of which are intended for the collection and measurement of the gases in a mixed, and others in a separate, state.

35. Faraday has further adduced experimental proofs, that variations in the size of the electrodes cause no variation in the chemical action of a given quantity of electricity upon water; that their action is not influenced by changes in the intensity, provided the quantity of electricity remain the same; that the quantity of water decomposed is not governed by the strength of the diluted sulphuric acid in the voltameter; that when other solutions are used in place of the acid, the constancy of the electrolytic action upon water is not altered; and that, notwithstanding all differences in the conditions and circumstances under which they may at the time be placed, the quantity of all electrolytes decomposed by the influence of current electricity, is exactly proportional to the quantity of electricity which passes.

36. But although the quantity of an electrolyte decomposed by the pile is proportional to the quantity of electricity passing, yet, as a compound submitted to voltaic action is generally an imperfect conductor, the quantity which actually does pass must vary with its intensity. For this reason, chemical decomposition must depend upon quantity and intensity together, and affords a criterion of the augmented tension of a compound circle arising from an increase in the number of its plates. The quantity of hydrogen gas, set free from decomposition of water in a given time, does not appear to vary in the simple ratio of the number of alternations; in other words, the gas is not doubled when the number of plates is doubled—the dissolution increases at a slower rate. Ritchie believed the ratio to be as the square root of the number of plates—so that when the number varies as 1 to 4, the gas evolved is as 1 to 2.

37. But, while we believe the electrolytic law, above enunciated, to be free from doubt, we must guard ourselves against its interpretation in favour of the chemical theory; for many well-founded objections can be raised against any such deduction; it shows that the quantities of bodies, decomposed in a given time, are proportioned to the chemical equivalents, but nothing more. It has no right to take a part in the question of the origin of voltaic electricity, and is equally correct whether the voltaic current originate from the contact of the metals, from the chemical action on the positive element, from fluid metallic contact, or from any other cause.

38. The error of using this law as an argument in favour of the chemical theory, appears to have originated from presupposing that which first ought to have been proved by it; namely, that the disturbance of the electric equilibrium was effected by the solution of the positive metal. It has occurred to this law as to the established principle, that the easily oxidized metals are for the most part the more positive. A connexion between the positive state and facility of oxidation is accordingly recognised; but which of these is *causal*, remains, as we have before stated, a subject of dispute. Its interpretation, however, in favour of the chemical theory, is the less justifiable, as several cases are known where the negative metal—although much more powerfully acted upon by acids than the positive—still continues negative to the latter. The fact observed by Ritter, Davy, Berzelius, and others, and recently confirmed by Poggendorff, that amalgamated zinc, though but very slightly attacked by dilute acids, is in these, considerably positive towards the so-easily-oxidized unamalgamated zinc, is one of many strong arguments against the chemical interpretation of this important law of Faraday.

39. But the fact that this law is not exclusively applicable to voltaic electricity, is sufficient evidence against the correctness of the inference sought to be deduced; if it were restricted to voltaic phenomena it would at the same time establish an essential difference between voltaic, magnetic, frictional, thermal, and animal electricity; but the law is not peculiar to voltaism, but, on the contrary, applies to all electric currents,—it being a property of all to decompose on their passage through a series of different fluids, equivalent quantities of each; therefore, *a priori*, every consequent deduction from the law, in regard to the origin of voltaic electricity, is untenable. That this is actually the case—that, in fact, the electrolytic law is common to all electric currents, and that consequently the identity of electricities of various origin, (abundantly proved by Faraday, and others, in other respects,) is established in relation to this law also—the experiment of Poggendorff, published not long since, on the simultaneous decomposition of two portions of water by the same magneto-electric current, leaves not the slightest room for doubt.

40. The agency of current electricity in producing decomposition of the fluid element of the circuit, or of any fluid though not an essential element, provided it be arranged in any part of the circuit, has been termed by Faraday "electrolysis," and the fluid thus capable of decomposition is denominated an electrolyte; all fluids, however, are not electrolytes, but only those whose elements combine in the lowest proportions; this law has been thus expressed by Faraday:—"There is but one electrolyte composed of the same two elementary ïons; hence, only single electro-chemical equivalents, and not multiples, can go to the electrodes." It may be, therefore, inferred, that in the electrolysis of a compound

formed of two elementary substances, the elements will be set free in single atomic proportionals; hence, the conclusion that water is to be looked upon as a primary atomic combination of single atoms of hydrogen and oxygen, which has led to the employment of electrolytic action in ascertaining the equivalent number of the elements of a compound in doubtful cases.

41. Electrolytic action tends not only to the separation of proximate, but also of ultimate elements; the decomposition of neutral salts affords numerous instances of the separation of the proximate elements of a compound—in these salts a compound acid, and a compound base, are respectively separated at the anode and cathode, as in the case of sulphate of baryta, sulphate of lime, &c. It is still a doubtful question whether the sub and super-salts are decomposed with precisely similar results; apparently they are; but the case is different with regard to binary compounds of the elementary substances; for, with very few exceptions, those only which are proto-compounds, consisting of one atom of an anion, and one of a cathion, are directly electrolytic.

42. The instances of apparent decomposition opposed to the foregoing law are very abundant, but may all be referred to secondary electrolytic action, which we must be careful in distinguishing from primary; for instance, nitric acid and ammonia, are each, though not electrolytes, decomposed by secondary action: thus, on submitting nitric acid to voltaic action, the water of the solution is electrolysed, and its hydrogen decomposes the acid, combining with a portion of its oxygen—to re-form water—and nitrous acid is produced. Many secondary actions are created in this way—the disunited elements being presented in a nascent form which is particularly favourable to combination;—when the electrolyte is an aqueous solution, or contains water, such secondary results are very frequent, though they are not restricted to such cases. Becquerel has shown, by the production of artificial minerals, that secondary action is available for the production of compounds, similar, in all respects, to natural products.

43. It has been ascertained that most of the elements are ïons; but some of the most important of those forms of matter, at present deemed elementary, such as nitrogen, carbon, phosphorus, boron, silicon, and aluminum, have not yet been shown to be ïons, which may arise from the difficulty of procuring these elements in compounds possessing the requisite conditions for electrolysis.

44. Electro-chemical decomposition cannot take place unless electricity is set in motion throughout the electrolyte; in other words, an electrolyte is always a conductor of electricity, except when its condition is changed by passing from a fluid to a solid state;—but, on the other hand, Faraday's and other experiments, go to prove, that conduction may take place through an electrolyte without decomposition. In this case, the current is of very feeble tension; but if its intensity be increased, or the conducting power of the liquid be improved, decomposition will be effected. If a solution of sulphate of soda be made part of a voltaic circle, in which electricity of low intensity is passing, the galvanometer will be affected—thus demonstrating the action—but no discoverable decomposition will occur; on increasing, however, the intensity of the current, the needle will not be further deflected, but the elements of the salt will be separated.

45. Electrolytes differ as to the degree of facility with which their elements are disunited by electric influence. A current of very feeble intensity suffices to decompose iodide of potassium, while a much more powerful tension is requisite for separation of the elements of water. The annexed bodies are easily decomposable in the order in which they are placed, those which are first being disunited by the least intensity:—

| | |
|---|---|
| Iodide of potassium | (solution,) |
| Chloride of silver | (fused.) |
| Protochloride of tin | (do.) |
| Chloride of lead | (do.) |
| Muriatic acid | (solution.) |
| Water acidulated by sulphuric acid. | |

46. A body not decomposable when alone, as boracic acid, is not directly decomposed by the electric current when in combination; it may act as an ïon, wholly going to the anode or cathode, but does not yield up its elements, except occasionally, by a secondary action. This principle, however, has no relation to such cases as that of water, which is rendered a better conductor of electricity by mixture with other bodies, and therefore is more easily decomposed.

47. The nature of the substance of which an electrode is composed, provided it be a conductor, causes no difference in decomposition in any respect, but it exercises an important influence by secondary action, on the state in which the ïons finally appear. This principle enables us to combine and collect those ïons, which, if evolved in their free state, would be quite unmanageable.

48. It would appear, that any force or action which tends to separate or remove farther apart the elements of any electrolyte, will promote the decomposition of that electrolyte; thus, the action of heat upon the electrolytic fluid in the circuit will cause an increased evolution of electricity, and a consequent increased decomposition. Sulphuric and other acids, salts, &c., appear to exercise a similar influence on water, by causing a wider separation of its molecules, and thus weaken the original, and promote new attractive forces.

# GEOLOGY.

## CHAPTER XII.

### OLD RED SANDSTONE, OR DEVONIAN SYSTEM.

The series of rocks which repose upon the Silurian system of Wales, and upon the schistose rocks of Scotland, is usually known by the name of "the old red sandstone." Mr Murchison has proposed to call it the "Devonian system," from its occurring extensively in Devon, and the adjoining counties in England and Wales. Geologists, previous to the recent discoveries made regarding the fossil fishes which characterize it, generally treated of it as the oldest member of the carboniferous system; but since these were made known to the world through the researches of Murchison, Miller, and Agassiz, its claim to a distinct place in the geological scale, has been universally conceded. The term old red sandstone, though sufficiently expressive of its lithological character in this country, and even in other parts of Europe, cannot be regarded as equally so of all deposits of the same age, it being highly improbable that the same mineral conditions could prevail in all parts of the world at that, or any other given time, any more than at the present day. The old red and the new red sandstone, bear in many places so striking a resemblance to each other in their mineralogical appearance, that it often becomes impossible to distinguish them, except by their stratigraphical position, or in other words, by the beds occurring above or below rocks of the carboniferous system, or by the presence of the fossils peculiar to either series; and as these occur rarely, and only in a few localities, the geologist is generally left to infer the age of the rocks he is contemplating, from their relative position with the superimposed or inferior strata.

The Devonian system attains great thickness in Scotland, and in England and Wales, and consists generally of sandstone of a reddish or brownish colour, often schistose or slaty in their structure, and unfit for building purposes. Some of the beds are occasionally white, gray, or variegated, and alternate with beds of clay, marl, or limestone of a red purple, gray, green, or variegated colours; at other places with beds of conglomerate composed of rounded pebbles of quartz, sandstone, and trap or slate. Beds of gypsum and salt were formerly considered as indicative of the new red sandstone, but these have been found in the old also, though not to the extent in which they occur in the new red. Such may be considered as a general description of the deposits of the Devonian system.

We are seldom able to trace a distinct passage from the rocks of one system to another in Scotland, each period seemingly having been separated from another by volcanic disturbance and deposition, on account of which, we almost always meet with a trap dyke or an overlying volcanic rock at the place where we expect to witness the junction with, or superposition of, the one system or series to the other—a circumstance which often proves peculiarly puzzling to the geological student. This remark holds particularly true with regard to the old red sandstone in the Scottish districts, where it occurs at the surface beyond the immediate limit of the coal formation. We have a very remarkable instance of this at Ardrossan, in Ayrshire, where on one side of a large trap dyke, the under beds of the coal formation are turned up at an angle of nearly eighty degrees, and on the other, the old red sandstone is deposited in gently inclined layers. The occurrence of trap between the schists and the old red, is also observable in different places, but in none which has come under our observation have we observed what may be termed distinct superposition.

One of the most remarkable features of the old red sandstone in the west of Scotland, is the occurrence of numerous trap dykes, preserving with each other a degree of parallelism, and generally passing from south-east to north-west; the same dykes also traverse the coal formation of Ayrshire, and the adjacent county of Renfrew. The trap dykes frequently occur in groups; four, five, or six of them, often occurring in a very short space. In the island of Arran, the old red sandstone occupies that portion of the coast which stretches from Currie to Laggantwine, and is chiefly composed of reddish coloured sandstone and beds of conglomerate. These rest unconformably on schist, and are conformably overlaid with a small development of the carboniferous rocks, which pass into an immense series of beds of red sandstone, red marl, and conglomerate, not to be distinguished from the older beds beneath the carboniferous layers. Instead of regarding these sandstone and conglomerate beds as belonging to either the new or old red sandstone, may we not consider them forming as a whole a representative of the carboniferous series? This, particularly with regard to the upper deposits of red sandstone and conglomerate, is the view entertained by Mr Murchison and others who have studied these formations. If this is the case, may we not then regard some of the red sandstones and conglomerates developed on the shores of the Clyde, both in the islands and on the main land, as also belonging to the coal era? The occurrence of coal in red sandstone and conglomerate in Bute, seems to warrant this conclusion. We mention these instances to show that little or no dependence can be placed on similarity of mineral composition in the determination of the age of any deposition whatever, where that cannot be satisfactorily ascertained by superposition, or the organic remains.

Organic remains occur rarely in sandstones and shales of a red colour; hence in many districts of the old red sandstone, none are to be found. We do not recollect of having met with a single trace of them in the red sandstones or conglomerates of the west of Scotland, and where they do occur as in the north of Scotland, and on its eastern coasts, they are not met with generally in the red, but in the dark-coloured rocks. The red colour is owing to the presence of the peroxide of iron, which appears to have been inimical to the existence of animal life in the medium of deposit. Why, it may be asked, are the sandstones of one age coloured red, while those of another are white? Is it owing to the greater quantity of iron or of oxygen that existed in the medium of deposition; or are we to attribute it to a different condition of the electrical agencies, by which rocks of all ages have been more or less affected? Some of the sandstones seem to warrant the latter supposition in preference to the former, a right line often separating both horizontally and vertically, the white from the red rock—a circumstance that seems to justify the conclusion that the colour has been induced subsequent to the time of deposition, as otherwise it would be difficult to conceive how the line separating the coloured portion from the white, should be so definite as we sometimes observe it in the old red sandstone flags of the formation. The general absence of organic remains in the red coloured portions appears to indicate some peculiarity in the medium of deposition, by which the colour may have been communicated to the deposited matter, and animals prevented from existing in the area of deposit. White circular spots are very common in the red sandstones, and as these penetrate the stone vertically, we must suppose some cause existing subsequent to or during the deposition of the sandy matter by which the peculiar oxidization of the mass has been prevented, or the colour expelled. These spots are supposed by some to have been owing to the presence of animal matter, but as they exhibit no trace of organization, may we not as justly suppose that they are owing to chemical causes?

The organic remains of the old red sandstone, have recently engaged much of the attention of geologists, particularly of that distinguished naturalist M. Agassiz. The most remarkable of the organisms of the formation is its fishes, an ample account of which will be found in Mr Miller's work on the old red sandstone.

Our limits forbid us from entering into detail on all the multifarious forms which geology has disclosed to our observation, nor, were we doing so, could it prove interesting to any of our readers, except such as have made comparative anatomy more or less their study, nor will our limits allow of more than a general notice of the most remarkable of those forms which peopled our planet prior to the existence of our own species. In contemplating these, the fishes are not the least remarkable.

In describing fossil fishes, their historian, Professor Agassiz, had recourse to the character of the scales and teeth, these being the best preserved, and in thousands of instances the only remaining portions from which a judgment could be formed, or a description given. In his classification he comprehends all existing as well as fossil fishes, which he divides into four grand orders, namely, the Placoideans, Ganoideans, Ctenoideans, and Cycloideans.

The Placoideans, (from *plaz*, a plate), comprehend all fishes which are covered with irregularly disposed enamened plates or scales of horn or bone, as in the Rays.

The Ganoideans, (from *ganos*, splendour), those fishes which have enamelled, round, square, or rhomboidal scales, or plates of bone or horn like the Lepidosteus, or bony pike.

The Ctenoideans, (from *cteis*, a comb), those fishes which have their scales indented or toothed like a comb on their posterior margin, as in the case of the Perch family.

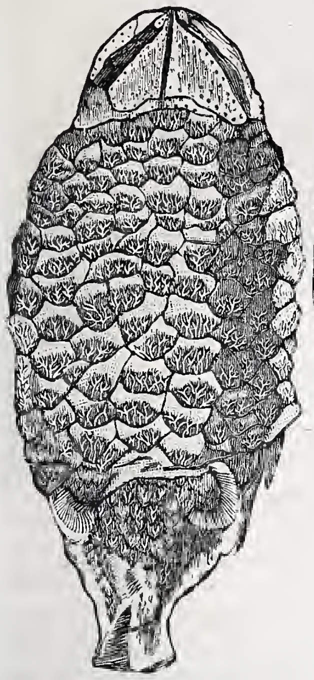
The Cycloideans (from *cyclos*, round), those which have round ornamented scales like those of the salmon or herring.

All the old fishes appear to have belonged exclusively to the first two of these orders, none of the remains of the others having been found in strata older than the chalk; and, from the nature of the teeth, which are generally sharp and conical, the great majority of them seem to have been of a sauroid character. The largest of these fishes seem to have existed in the carboniferous era, the fishes of the old red sandstone being remarkable for their singularity of form, rather than their great size. We are indebted to Mr Hugh Miller, author of the interesting little work already referred to, for the discovery of several genera and species of fishes in the old red sandstone of Caithness and Forfarshire, that are quite unlike the form or character of any fish with which we were hitherto acquainted, in either the living or the fossil state. Among these the most extraordinary are the Pterichthys, or winged fish—the Cephalaspis and the Holoptychius—animals which form the connecting link between the Crustaceans and Reptiles, and of which the following cuts are figures copied from Mr Miller's work.

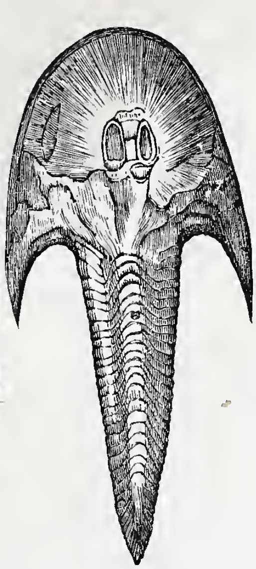
The Holoptychius is common to the old red sandstone, and the coal formation. None of the other fishes are so; but, as far as research has yet gone, belong exclusively to the former.

"We find," observes Mr. Miller, "the organisms of the old red sandstone supplying an important link, or rather se-

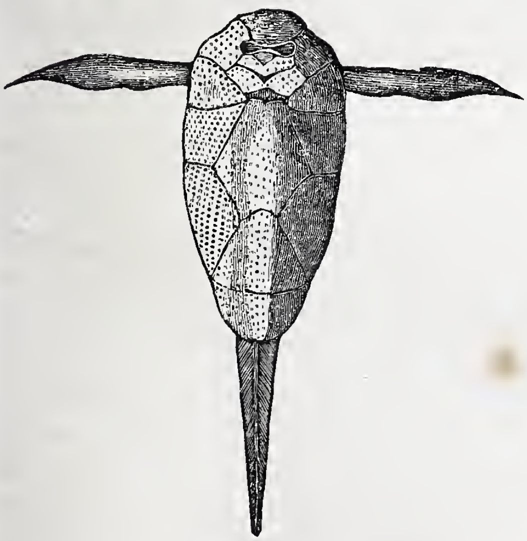
ries of links, in the ichthyological scales, which are wanting in the present creation, and the absence of which evidently



Holoptychius nobilissimus.



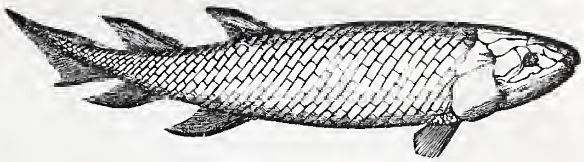
Cephalaspis Lyellii.



Ptericthys Milleri.

occasions a wide gap between the two grand divisions or series of fishes—the bony and the cartilaginous. Of all the organisms of the system, one of the most extraordinary, and in which Lamarck would have delighted, is the *Ptericthys,* or winged fish, an ichthyolite which the writer had the pleasure of introducing to the acquaintance of geologists nearly three years ago, but which he had laid open to the light about seven years earlier. Had Lamarck been the discoverer, he would unquestionably have held that he had caught a fish in the act of wishing itself into a bird. There are wings which only want feathers, a body which seems as well adapted for passing through air as water, and a tail by which to steer. And yet there are none of the fossils of the old red sandstone which less resemble anything that now exists than its Ptericthys. The body was of very considerable depth, perhaps little less so, proportionally, from breast to back, than the body of the tortoise; the under part was flat, the upper rose towards the centre into a roof-like ridge, and both under and upper were covered with a strong armour of bony plates, which, resembling more the plates of the tortoise than those of the crustacean, received their accessions of growth at the edges or sutures. The eyes are placed in front, and the mouth seems to have opened on the edge of the snout. It was furnished with two arms, or wing-shaped paddles, and a tail covered with minute angular plates, like scales."

The other fishes described by Mr Miller as belonging to the old red sandstone, are more allied to common fishes, yet sufficiently wonderful in their structure to excite surprise.



Osteolepis.

"The Osteolepis was cased from head to tail in complete armour. The head had its plated mail; the body its scaly mail; the fins their mail of parallel and jointed bars; the entire suit glittered with enamel, and every plate, bar, and scale, was dotted with microscopic points. Every ray had its double or triple punctulated row; every scale or plate its punctulated group. The markings lie as thickly, in proportion to the fields they cover, as the circular perforations in a lace veil, and the effect viewed through the glass, is one of lightness and beauty. In the Cheirolepis, an entirely different style obtains. The enamelled scales and plates glitter with minute ridges, that show like thorns in a December morning, varnished with ice. Every ray of the fin presents its serrated edge; every occipital plate and bone its sculptured prominences; every scale its bunch of prickle-like ridges. A more rustic style characterized the Glyptolepis. The enamel of the plates and scales is less bright. The sculpturings are executed on a larger scale, and more rudely finished. The relieved ridges, waved enough to give them a pendulous appearance, drop adown the head and body. The rays of the fins, of great length, present also a pendulous appearance. The bones and scales seem disproportionately large. There is a general rudeness in the finish of the creature, if I may so speak, that reminds one of the tatooings of a savage, or the corresponding style of art in which he ornaments the handle of his stone hatchet or war club. In the *Cheiracanthus,* on the contrary, there is much of a minute and cabinet-like elegance. The silvery smoothness of the fins, dotted with scarcely visible scales, harmonized with a similar appearance of head; a style of sculpture resembling the parallel etchings of the line engraver, fretted the scales; the fins were small, and the contour elegant."

As we have formerly noticed, fishes make their first appearance in the upper beds of the Silurian rocks, but it is in the old red sandstone, where, on account of their extraordinary and well-developed forms, the study of them becomes definite and deeply interesting. According to Agassiz, no two mineral formations contain the same fishes, the species in each being quite distinct from those of another. With what interest, then, must we regard these—the first, created of the many thousands of species which, since the period of the old red sandstone, have moved through the waters of the ocean, preying on each other, and otherwise performing the offices for which they were adapted, by their peculiar organizations in the economy of Nature!

# MATHEMATICS.

## CHAPTER XI.

### REDUCTION OF UNITS OF ONE DENOMINATION TO UNITS OF ANOTHER DENOMINATION.

Our last chapter was devoted to the explanation of the different units by which we express compound quantities—that is, quantities made up of different magnitudes. As already intimated, by thus establishing a scale of units of different magnitudes, we avoid the inconvenience of having only one unit, which, if small, would often make it necessary to employ very large numbers; and, if large, would encumber our operations with fractions. The mode adopted to express a quantity, is simply to state how many times the greatest magnitude (not greater than the thing in question,) is contained in it; then how many times the next greatest is contained in the part over, and so on to the least part. Thus, the sum of money, £5 15s. 8d.; the length 6 yards 2 feet 7 inches; and the weight 2 cwt. 1 quarter 17 lbs., are compound quantities, and the different units by which they are respectively expressed are called units of different denominations —that is, units of the same kind, but of different magnitudes.

From the nature of this notation it is easy to perceive that the value of compound quantities may be measured in several different ways. Thus, the sum of money which we call six pounds eleven shillings, might be called 131 shillings, or 1572 pence, or 6288 farthings; and, conversely, 3648 farthings may be called 912 pence, or 76 shillings, or three pounds sixteen shillings. The operations by which quantities are thus changed from one denomination into another constitute Reduction. Of this there are manifestly two cases—the first, when the reduction is to be made from a higher to a lower denomination, and the second when it is to be made from a lower to a higher denomination.

As an example of the first case, let it be required to find how many farthings there are in £7 18s. $9\frac{3}{4}$d. ?*

Since there are 20 shillings in £1; there are in £7, manifestly $7 \times 20 = 140$ shillings; therefore, in £7 18s. there are $140 + 18 = 158$ shillings. Since there are 12 pence in a shilling, in 158 shillings there are $158 \times 12 = 1896$ pence; and, therefore, in £7 18s. 9d. there are $1896 + 9 = 1905$ pence. And, since there are 4 farthings in a penny, in 1905 pence there are $1905 \times 4 = 7620$ farthings; and, therefore, in £7 18s. $9\frac{3}{4}$d. there are $7620 + 3 = 7623$ farthings. This process, for the sake of convenience, may be written as follows :—

£7 18s. $9\frac{3}{4}$d.
20
$140 + 18 = 158$ shillings.
12
$1896 + 96 = 1905$ pence.
4
$7620 + 3 = 7623$ farthings.

As an example of the second case, let it be required to find how many pounds, shillings, pence, and farthings, there are in 7623 farthings?

Since a farthing is the $\frac{1}{4}$th of a penny, in 7623 farthings there are $\frac{7623}{4} = 1905$ pence and 3 farthings. Since a penny is $\frac{1}{12}$th of a shilling, in 1905 pence there are $\frac{1905}{12} = 158$ shillings and 9 pence. And, since a shilling is $\frac{1}{20}$th of £1, in 158 shillings there are $\frac{158}{20} =$ £7 and 18 shillings. Therefore, 7623 farthings are $1905\frac{3}{4}$d., which is 158s. $9\frac{3}{4}$d., which is £7 18s. $9\frac{3}{4}$d.

The process may be written for convenience in the following form :—

4) 7623 farthings.
12) $1905\frac{3}{4}$
20) $158 : 9\frac{3}{4}$
£$7 : 18 : 9\frac{3}{4}$

* Farthings are only written as fractions of a penny—the number of farthings in a penny, namely, 4, being the denominator. Two farthings, or one halfpenny, may be written either $\frac{2}{4}$ or $\frac{1}{2}$; the latter is most common.

These examples illustrate both processes sufficiently, but, for the sake of variety, we shall take another example—how many drams in 505 tons 2 cwt. 0 qr. 11 lbs. 10 oz. 12 dr.?

Since 20 cwt. make a ton, therefore, in 505 tons there are $505 \times 20 = 10100$ cwt., and 10102 cwt. in 505 tons 2 cwt. There are 4 qrs. in a cwt., therefore, in 10102 cwt., there are $10102 \times 4 = 40408$ qr.; and since 28 lb. make a qr., therefore, in 40408 qr. there are $40408 \times 28 = 1131424$ lb.; and, consequently, in 505 tons 2 cwt. 0 qr. 11 lb. there are $1131424 + 11 = 1131435$ lb. Again, since there are 16 oz. in a lb., in 1131435 lb. there are $1131435 \times 16 = 18102960$ oz., and in 505 tons 2 cwt. 0 qr. 11 lb 10 oz., there are, therefore, $18102960 + 10 = 18102970$ oz. Lastly, since there are 16 dr. in an oz., therefore, in 18102970 oz. there are $18102970 \times 16 = 289647520$ dr., and in 505 tons 2 cwt. 0 qr. 11 lb. 10 oz. 12 dr. there are $289647520 + 12 = 289647532$ drams.

This process may be written down as follows :—

505 tons 2 cwt. 0 qr. 11 lb. 10 oz. 12 dr.
20 = No. of cwts in a ton.

10102 = No. of cwts. in 505 tons 2 cwts.
4 = No. of qrs. in a cwt.

40408 = No. of qrs. in 505 tons 2 cwts. 0 qr.
28 = No. of lbs. in a qr.

1131435 = No. of lbs. in 505 tons 2 cwt. 0 qr. 11 lb.
16 = No. of oz. in 1 lb.

18102970 = No. of oz. in 505 tons 2 cwt. 0 qr. 11 lb. 10 oz.
16 = No. of dr. in 1 oz.

289647532 = No. of dr. in 505 t. 2 cwt. 0 qr. 11 lb. 10 oz. 12 dr.

The converse of this process will exemplify the second case, and furnish this question: How many tons in 289647532 drams?

The operation might be gone through analytically, but we shall leave that part to the student, and simply write it down in the most convenient practical form, as a pattern for all similar questions which can arise.

16 { 4) 289647532 drams.
  { 4) 72411883
16 { 4) 18102970 and $\frac{3}{4}$ of 16 dr. = 12 dr.
  { 4) $4525742\frac{1}{2}$
28 { 7) 1131435 and $\frac{2\frac{1}{3}}{4}$ of 16 oz. = 10 oz.
  { 4) $161633\frac{4}{7}$
4) 40408 and $\frac{1\frac{4}{7}}{4}$ of 28 lb. = 11 lb.
2,0) 1010,2
505 tons 2 cwt. 0 qr. 11 lb. 10 oz. 12 dr.

In dividing by 20 it will be observed, that the 0 of the divisor, and the 2 of the dividend, are respectively pointed off, leaving the real divisor 2. This is uniformly practised in reducing shillings to pounds sterling, and cwts. to tons, and, indeed, (as explained in 16 and 17 of chapter iv., p. 142, Vol. I,) may be always practised when the divisor has ciphers annexed to it. The remainders may be found in cases where the division is effected by the factors of the given divisor, by the rule given in article 13 of chap. iv.; but if the nature of fractions be well understood, it will not be requisite to have recourse to that rule. This, however, will be further explained in the present article.

The method of performing the operations of both cases may now be described in the following rules :—

Case I.—To reduce units of a higher denomination into those of a lower, multiply the given number of the highest denomination by the number of times that the unit of the next lower denomination is contained in it, and this product by the number of times that the unit of the third denomination is contained in that of the second; proceed in this way multiplying always by the number of times that the unit of the next lower denomination is contained in the denomination arrived at, until the required denomination be reached. Should the given quantity contain units of different denominations, the given numbers of the lower denomination must successively be added to the products, which are of the same denominations (as shown in the examples above); and should the given quantity contain units

only of one denomination, it *may* be multiplied at once by the number of units of the required denomination which make *one* of the given denomination. Thus, to reduce 12 acres to sq. yds., we require only to multiply 12 by 4840, the number of sq. yds. in one acre.

CASE II.—To convert units of a lower denomination into those of a higher, divide the given quantity by the number of times that the unit in which it is expressed is contained in a unit of the next higher denomination, and note the remainder; divide the whole part of this quotient again by the number of times that the unit of *its* denomination is contained in that of the next higher, noting the remainder as before; proceed in this way till the denomination required be reached: the several remainders are numbers of the several lower denominations. Sometimes it is more convenient to obtain only the units of the lower denominations as a single fraction of a unit of the highest denomination, and in this case the easiest way is to divide at once by the number of the given denomination which makes one of the required denomination. Thus, supposing we require to know how many hours, and parts of an hour, there are in 75671 seconds, we divide by 3600 (that is $60 \times 60$,) which gives $21\frac{71}{3600}$ hours.

We may here present the following table, which will afford about as much exercise on these rules as is necessary to enable the student to apply them with facility. The quantities written opposite to each other are the same; so that each line furnishes two exercises:—

| | |
|---|---|
| £5 8 $6\frac{1}{2}$ | 2605 halfpence. |
| £18 12 $6\frac{3}{4}$ | 17883 farthings. |
| 25 lb. 0 oz. 3 dwt. | 144072 grains. |
| 3 tons, 9 cwt. 8 lb. | 123776 ounces. |
| 3 miles, 149 yds. 2 ft. 9 in. | 195477 inches. |
| 20 yds. 3 nails. | $726\frac{3}{4}$ inches. |
| 9 rds. 8 poles 8 feet. | 14428224 square inches. |
| 13 qrs. 3 pecks 3 quarts. | 6662 pints. |
| 589 wks. 4 hours 3 minutes. | 59376363 minutes. |

A has £100 4s. $11\frac{1}{2}$d, and B has 64392 farthings. If A receive 1492 farthings, and B £1 2s. $3\frac{1}{2}$d, which will then have most, and how much?

*Ans.*—A will have £33 12s. 3d. more than B.

Sometimes it is required to convert units of one magnitude into those of another, when the one magnitude is not an exact measure of the other. This is in general done by finding some denomination which forms a part of both; reducing the given quantity to units of that denomination, and these again to units of the required denomination. Thus, supposing it required to reduce 12 lbs. avoirdupois to lbs. troy, we know that a lb. avoirdupois contains 7000 grains troy, and therefore 12 lbs. avoirdupois $\times$ 7000 = 84000 grs. troy; and by the inverse operation we find 84000 troy grs. = 14 lb. 7 oz. troy.

As a question of the same class, suppose a piece of cloth to measure 17 yards, 2 qrs. 1 nail, by stretching it unduly an inch each yard, what is the true length of the piece?

*Ans.*—17 yds. 0 qrs. 1 nl. $0\frac{7}{16}$ in.

The preceding rules are easily adapted to fractions. For, bearing in mind, that to multiply a fraction by an integer, we multiply the numerator; and to divide a fraction by an integer we multiply the denominator by the integer, it is necessary only to perform the operations according to these principles in applying the rules.

Thus, to convert £$\frac{7}{11}$ into an equivalent fraction of a lower denomination—of a penny for instance, multiply the numerator by 240, the number of pence in £1, and we have £$\frac{7}{11} = \frac{1680}{11}$ of a penny.

Again, to convert $\frac{2}{3}$ of a farthing into an equivalent fraction of a higher denomination, to the fraction of a pound for instance—multiply the denominator by 960, the number of farthings in £1, and we have $\frac{2}{3}$ of a farthing = £$\frac{2}{2880}$ = £$\frac{1}{1440}$.

The rule for such reductions, therefore, is—To convert a fraction of a higher denomination into that of a lower, multiply the numerator. To convert a fraction of a lower denomination into that of a higher, multiply the denominator. In either case, multiply by the number of the lower denomination which makes one of the higher. It will also be borne in mind that, to divide the denominator of a fraction is the same as to multiply its numerator, and *vice versa.*

The following instances will serve for exercise on this rule:—

| | | |
|---|---|---|
| £$\frac{11}{120} = \frac{11}{10}$s. | $\frac{33}{64}$ qr. = $\frac{231}{16}$ lb. | $\frac{1}{300}$ lb. troy = $\frac{4}{5}$ dwt. |
| $\frac{6}{7}$d. = $\frac{1}{14}$s. | $2\frac{4}{7}$ qr. = $\frac{9}{14}$ cwt. | £$\frac{1}{7} = \frac{20}{147}$ guinea. |

Instead of reducing the fraction of a higher denomination into that of a lower, it is often necessary in actual calculation, to convert the fraction into a compound quantity, or, as it is called, to value the fraction. This is done by dividing the numerator at each successive step of the reduction. For example, let it be inquired how many shillings and pence there are in £$\frac{7}{8}$? By £$\frac{7}{8}$ is meant $\frac{7}{8}$ of 20 shillings, that is $\left(\frac{7 \times 20}{8}\right)$s., or $\left(\frac{7 \times 5}{2}\right)$s. or $\left(\frac{35}{2}\right)$s. or $17\frac{1}{2}$s. Again, $\frac{1}{2}$s. is $\frac{1}{2}$ of 12 pence, or $\left(\frac{1 \times 12}{2}\right)$d. or 6d. Therefore £$\frac{7}{8}$ = 17s. 6d.

The principle is even more simply applied when the given fraction is a decimal. Thus £·484375 is ·484375 $\times$ 20 in shillings, that is 9·6875 shillings; and ·6875 of a shilling is ·6875 $\times$ 12 in pence, that is 8·25 pence; and ·25 of a penny is ·25 $\times$ 4 in farthings, that is 1 farthing. Whence £·484375 is 9s. $8\frac{1}{4}$d.

These two examples may now be written as under:—

$$\text{£}\,\frac{7}{8} = \left(\frac{7 \times 20}{8}\right)\text{s.} = \frac{140}{8}\text{s.}$$
$$\text{and } \frac{140}{8}\text{s.} = \frac{35}{2}\text{s.} = 17\tfrac{1}{2}\text{s.}$$
$$\text{and } \frac{1}{2}\text{s.} = \frac{1 \times 12}{2}\text{d.} = 6\text{d.}$$
$$\text{Therefore, £}\,\frac{7}{8} = 17\text{s. }6\text{d.}$$

```
    £·484375
          20
(9)·687500 shillings.
          12
(8)·250000 pence.
           4
(1)·000000 farthings.
```

In questions such as this last, it is unnecessary to write the ciphers upon the right in practice.

The following questions will afford additional exercise in these operations:—

| | |
|---|---|
| £$\frac{37}{60}$ = 12s. 4d. | £·7575 = 15s. $1\frac{3}{4}$d. $\frac{1}{5}$. |
| $\frac{6}{7}$ lb. = 10 oz. 5 dwt. $17\frac{1}{7}$ gr. | ·6875 cwt. = 2 qr. 21 lb. |
| $\frac{4}{9}$ lb. = 7 oz. $1\frac{7}{9}$ dr. | ·0078125 cwt. = 14 oz. |
| $\frac{107}{428}$ mile = 2 furlongs. | ·05875 lb. avoird. = 15·04 dr.* |
| $\frac{5}{8}$ of $\frac{3}{5}$ of an acre = $1\frac{1}{2}$ rood. | ·23 of a day = 5 hr. 31 m. 12 s. |
| $\frac{11}{18}$ of a day = 14 hr. 40 m. | ·04535 m. = 14 p. 2 y. 2 f. 5·375 in. |
| $\frac{15}{32}$ qr. wheat = 3 bhl. 3 pks. | ·671875 y. = 2 qr. 2 nails $1\frac{1}{16}$ in. |

The converse of these operations is the reduction of a compound quantity to the form of a fraction. Thus suppose it required to find what part of a pound 6s. 8d. is. Since 6s. 8d. is 80 pence, and since the whole pound contains 240 pence, 6s. 8d. is that part which is found by dividing the pound into 240 parts, and taking 80 of them: it is therefore £$\frac{80}{240}$; but $\frac{80}{240} = \frac{1}{3}$; Therefore £$\frac{80}{140}$ = £$\frac{1}{3}$; and therefore 6s. 8d. = £$\frac{1}{3}$.

Again, suppose it required to express 4s. $8\frac{1}{4}$d. as the decimal of a pound. Since 4s. $8\frac{1}{4}$d. = 225 farthings, and since one farthing = £$\frac{1}{960}$, therefore 225 farthings = £$\frac{225}{950}$. But $\frac{225}{960}$ = ·234375. Therefore, £$\frac{225}{960}$ = £·234375; and, hence, 4s. $8\frac{1}{4}$d. = £·234375.

This example shows the general principle upon which operations of this sort are conducted; but, in practice, the following is more convenient:—

```
£0 : 4 : 8¼
  4)1·00
 12)8·25
 20)4·6875
   £·234375
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The mode is to put down the number of the lowest denomination, and reduce it to the decimal of the next higher denomination. Thus, the farthing is reduced in the first instance to the decimal of a penny. On the left of the decimal point is then written the number of the next higher denomination in the given quantity, and the result is then reduced to the decimal of the next higher unit. And so on. Thus 1 farthing is first put down; this is equivalent to ·25 of a penny; on the left is written the 8d., making 8·25, which, divided by 12, gives the decimal ·6875 of a shilling. The 4 shillings being prefixed to this decimal, and the result divided by 20 gives the decimal of a pound as required.

This calculation, in the case of money, admits of abridgment. Since one shilling is $\frac{1}{20}$th of a pound, any number of shillings

* When a decimal follows a whole number, it is in all cases of the same unit as the number to which it is attached. Thus 15·04 drams is 15 drams and 4 hundredths of a dram.

are so many twentieths of a pound. Now, $\frac{1}{20} = \frac{1}{2}$ of $\frac{1}{10}$, whence any number of shillings are half as many tenths of a pound. Thus, 8s. and 12s. are respectively £·4, and £·6. Again, since one farthing is $\frac{1}{960}$th of a pound, any number of farthings are so many 960th parts of a pound. Now, $\frac{1}{960}$ is greater than $\frac{1}{1000}$ by $\frac{1}{24}$ of $\frac{1}{1000}$. Whence, if to any number of farthings we add $\frac{1}{24}$ of the whole, the number thus increased will express so many thousandth parts of a pound. Hence, we may readily convert shillings, pence, and farthings, into decimals of a pound mentally by this rule:—Take half the number of shillings as the first decimal place, convert the remainder of the given sum into farthings, and increase the number by 1 for every 24 in it, and write down the result as the second and third figures of the decimal.

Thus, to express 17s. 7½d. as a decimal, take half of 16s., that is 8s. as the first decimal figure. Then the remainder, 1s. 7½d. = 78 farthings, which, increased by 3, (the number of times that 78 contains 24,) gives 81 as the second and third figures; hence, 17s. 7½d. = £·881 (nearly).

This process gives a result of only three figures; but, if greater accuracy be wanted, it may be obtained by taking into account the *exact* number of times that 24 is contained in the farthings. Thus, 24 is contained 3¼ times in 78; therefore, 3¼ ought to have been added to 78 making 81¼, so that £·88125 is the decimal exactly.

It may also be observed that, instead of taking half the number of shillings for the first decimal figure, we may multiply the shillings by 5 for the two first figures. This is clear, since $\frac{1}{20} = \frac{5}{100}$ or ·05, or since 1s. is £$\frac{5}{100}$. We have then to reduce the pence and farthings of the remainder to farthings, add 1 for every 24 of the number, and make three decimal places of the result by prefixing a cipher. The two results being then added together, the sum is the decimal required.

Thus to express 19s. 6¾d. as the decimal of a pound, we have 19s. × 5 = £·95; and 6¾d. is 27 farthings, which increased by 1 becomes 28; therefore 6¾d. = £·028. Hence 19s. 6¾d. = £(·95 + ·028) = £·978.

The converse of the preceding rule is to value a decimal of a pound mentally. The process must clearly be the reverse of the last; that is, double the first decimal place, and add one to the product *if the second place be 5 or upwards:* the result is the number of shillings. Take the quantity that is left as a simple number; diminish the tens' figures by 5, when it is 5 or upwards, and finally subtract 1 as often as 25 is contained in the number, and the result is the number of farthings, which must be turned into pence and farthings.

What is £·876? This may be separated into £·85 and £·026; now the 8 doubled and increased by 1 gives 17 for the number of shillings. The number in the second is 26, which diminished by 1 gives 25 for the number of farthings. Hence £·876 is 17s. 6¼d.

We append the following examples for practice in both rules.

| | |
|---|---|
| £·512 = 10s. 3d. | £·024 = 0s. 5¾d.* |
| £·065 = 1s. 3¾d. | £·956 = 19s. 1½d. |
| £·981 = 19s. 7½d. | £·103 = 2s. 0¾d. |

In calculations where greater accuracy is required than those rules ensure, the common rules must be employed.

* 24 is nearly 25, and therefore we deduct 1.

## THEORY AND PRACTICE OF DYEING.

### CHAPTER IV.

PREPARATION OF CHEMIC—CHEMISTRY OF THE BLUE VAT.

The only substance which dissolves indigo, without destroying its colour and composition, is highly concentrated sulphuric acid. For this purpose, the fuming acid of Nordhausen is preferable,† as, when other acid is used, a greater quantity of it is required. The substance formed is popularly known by the names of sulphate of indigo, Saxon blue, China blue, and extract of indigo. The action of sulphuric acid upon indigo is found to be something more than a mere solution: a chemical combination, in definite proportions, results, forming two distinct substances, differing considerably from each other in their properties. These two compounds were discovered and described by Mr. Crum, and called by him *cerulin* and *phinacin*, from their colours—the former blue, and the latter purple. They have been since named sulph-indylic acid, and sulpho-purpuric acid. The former, which constitutes the blue principle of Saxon blue, is formed most abundantly when the sulphuric acid is sufficiently strong and abundant, and other proper means, to be noticed, attended to. Its composition is found to be one atom of indigo combined with two of sulphuric acid. The other is the principal product when the indigo preponderates. It is of a purple colour; and when the solution is diluted with water, it precipitates. Its composition is found to be equal to one atom sulphuric acid to one of indigo.

† Sulphuric acid, procured by distilling sulphate of iron (copperas).

From the nature and properties of these two substances, it is evident that every care should be taken to convert the indigo into sulph-indylic acid, and to avoid the formation of sulpho-purpuric acid. The circumstances under which this latter acid is formed are—first, too little acid, in proportion to the indigo. The general proportions used by dyers vary from three to five pounds of acid to the pound of indigo. This is by far too little, and occasions a considerable loss of indigo by the precipitation of the sulpho-purpuric acid, when the solution is mixed with water. Close observation shows that it requires from six to eight pounds of the fuming sulphuric acid to convert a pound of indigo into blue sulph-indylic acid, and will require from eight to ten of the strongest English sulphuric acid to give the same results. From some investigation lately made by M. Dumas, an eminent French chemist, indigo requires even a larger proportion of acid to convert it into sulph-indylic acid. He recommends no less than fifteen parts of acid to one of indigo. This quantity, however, would be very annoying where it is all to be precipitated by lime.

Another circumstance under which sulpho-purpuric acid is formed is, too short time being given for the indigo and acid to digest. When indigo is first put into the sulphuric acid, there seems to be an immediate solution; but if a drop be spread upon a window pane, it appears of a dirty green colour. If this be allowed to stand for a little upon the glass, a yellowish-coloured liquid begins to run from the blue mass, occasioned, no doubt, by the acid absorbing moisture, and separating itself from the indigo, and clearly showing that the change upon the indigo by the acid is not an immediate effect. The more impure the indigo, the darker and greener appears the substance when put upon the glass. After the mixture has stood two or three hours, and tried in the same manner, it appears of a reddish purple colour,—the principal compound existing now in the solution being sulpho-purpuric acid. As the liquid stands, it begins to assume a violet shade, and finally passes to a deep rich blue. But dyers seldom obtain it in this state: in their hands it generally has a reddish tinge. Mr Crum found that when the solution is diluted with water, after the colour has become of a bottle-green, the action of the acid is stopped, and sulpho-purpuric acid only is formed. But there are other means by which the action of sulphuric acid upon indigo may be stopped, than by directly diluting the solution with water. As already intimated, it is only the highly concentrated sulphuric acid which converts indigo into sulph-indylic acid. Now, dyers not unfrequently alter the strength of their acid, by the process of mixing and preparing their *chemic.** This is very generally done in an open, wide-mouthed vessel, which is allowed to stand uncovered, probably in the midst of the steam and vapours of the dye-house; or, in some cases, the vessel is put into a boiler, or tub with boiling water. By these injudicious means, the sulphuric acid, which absorbs water very rapidly, is diluted below the necessary strength for dissolving indigo; and the result is, the formation of sulpho-purpuric acid, instead of sulph-indylic acid, which is the real substance wanted.

Another cause of the stopping of the action of the acid by dilution is, from the indigo. Ground indigo absorbs a quantity of moisture; and if it be not thoroughly dried previous to putting it in the acid, the acid is too much weakened to effect the formation of the substance required.

There are other causes by which the preparation of *chemic* is injured. Sometimes the acid and indigo are mixed together at once, and by this means the heat evolved is sufficient to decompose the impurities of the indigo. Part of the acid also suffers decomposition, and a great quantity of sulphurous acid gas is given off,—so much, indeed, that the head cannot be held above

* The technical name for sulphate of indigo.

the vessel for any length of time without injury. Another practice is—for the sake of quickening the operation—to place the vessel upon the flue in the stove, and keep the solution for hours at a heat upwards of 300° F. The gas given off in these cases is sometimes so great as to destroy the colours of goods hanging in the stove. Indigo submitted to such treatment is seldom found good: often its appearance on the glass (which is a general method of testing the quality of sulphate of indigo) is a blackish green—sometimes a dirty purple—seldom the fine blue violet—scarcely ever the beautiful blue.

Although the sulpho-purpuric acid is precipitated when water is mixed with the solution of sulphate of indigo, and is insoluble in dilute acids, it is, when freed from the sulphuric acid, soluble in distilled water; but if any substance be in the water—and common spring water is never pure,—it is less soluble. It dissolves in alkalis, and in solutions of the alkaline earths, giving a blue colour, of greater or less purity, according to the nature of the solvent.

We have found the following method of preparing sulphate of indigo, in quantities for use, very satisfactory:—The indigo is reduced to an impalpable powder, either by grinding in a mortar or a mill, and completely dried, by placing it upon a sandbath or flue for some hours, at a temperature of about 140° or 150° F. For each pound of indigo, ten pounds of highly concentrated sulphuric acid are put into a large jar, or earthen pot, furnished with a cover. This is kept in as dry a part as possible, and the indigo is added gradually, in small quantities. The vessel is kept closely covered, and care taken that the heat of the solution does not exceed 212° F. When the indigo is all added, the vessel is placed in such a situation, that the heat may be kept at about 150° F., and allowed to stand, stirring occasionally, for forty-eight hours. These precautions being attended to, we have uniformly found that any failure occurring was clearly tracible to impurity of the indigo, or weakness of the acid used.

Chemic blue is used for various operations in dyeing. When diluted with twenty times its quantity of boiling water, and allowed to settle, it is sometimes used for dyeing colours upon wool and silk—especially for greens upon the latter substance. A little carbonate of potash is added by some with the boiling water, and the clean solution used as above. When fine light shades, such as sky-blue, &c., are wanted, this diluted liquor is boiled or digested with a piece of woollen cloth, which takes up the blue colour; what remains is a greenish-coloured substance, probably the impurities of the indigo. The cloth is washed with cold water, and kept for use. When light shades are to be dyed, this cloth is put through hot water, which extracts a quantity of the blue which is used for the dye. When warm water ceases to extract enough, a very minute quantity of a carbonated alkali is added, which *bleeds*, as dyers term it, the colour from the cloth. The method of preparing chemic for dyeing green upon light cotton goods, is, perhaps, the nicest of all its preparations. The acid solution of indigo is put into about twenty gallons of boiling water to the pound of indigo. Exact measurement is not material. In mixing this solution with the hot water, it is known whether the indigo and the acid are in complete combination; if they are not, the acid sputters and boils in the same manner as vitriol does when poured into hot water; if they are combined, it goes down into the hot water as calm as water would do poured into oil. To this mixture, finely pounded chalk or whitening, is added by degrees, until the acid is exactly neutralized. This is the most particular part of the operation. Although a pound of whitening to the pound of acid used, comes very near the proportion, yet there are so many circumstances which may alter measured proportions that they cannot be relied upon. Were the acid property to prevail in the least, it would destroy the yellow upon the cloth to be dyed green; and were the alkaline matter predominant, it would brown the yellow, and the green would assume a blackish-olive shade. Thus the beauty of the colours depends upon the dyer being careful just to stop at the turning point. The only method employed by dyers for determining the point of neutrality is the taste; and this, from many circumstances which we need not enumerate, is liable to error; and when the dyer is deceived, the results are very annoying, and also expensive. Were very delicately prepared blue and red litmus papers used, the results would be much more certain. However, the reader may be astonished when we inform him, that scarcely one instance out of ten goes wrong from this cause. Some dyers use carbonated alkalis, such as soda and potash, to neutralize their acid; and no doubt when any of these are used, the sediment at the bottom is much less; but we have always thought this owing to the salts formed by these alkalis being dissolved in the blue solution, and have invariably found that the green colour was not so good, especially if *bark* was the yellowing substance. The process of dyeing greens by this sort of prepared chemic is as follows:—The goods, after being well boiled and washed, are put through a dilute solution of pyroligneous acid of sp. gr. 1·035, that is 7 of Twaddel, and washed from this through hot water; they are then wrought through a decoction of *quercitron bark*. When sufficiently yellow for the shade of green required, they are wrought through a quantity of chemic mixed with cold water; wrung from this and dried. If fustic is the yellowing substance used, alum is a better mordant. But this will be treated of in its proper place.

The greatest portion of the indigo imported is used for dyeing blue by means of the blue vat. We have already mentioned that indigo is insoluble, except in strong sulphuric acid;* but if it be by any means deprived of an atom of oxygen, (according to the common theory,) it is soluble in alkalis. It may be said, that, according to the law of definite proportions described in our first article, it cannot be indigo with an atom less of oxygen. Neither is it; and we see that it has different properties from common indigo, for it is soluble even in weak alkalis; has a powerful attraction for oxygen; and is of a white colour. This substance has been termed *indigogen*, and it may be observed, that the nature of the blue vat depends upon the introduction of substances capable of extracting oxygen from the indigo, and converting it into *indigogen*. The substances generally used for this conversion are the protoxides of iron and tin, orpiment (sulphuret of arsenic,) and organic substances. These last produce the desired effect by their decomposition, such as in the woad vat, where, by the fermentation of the woad and madder, the oxygen is extracted from the indigo, which is thus converted into indigogen. The indigogen is dissolved as it forms by the potash put into the vat.

What is termed the common blue vat, or lime vat, is made up with indigo, lime, and sulphate of iron (copperas.) But before describing the nature of this vat, it will be necessary to say something upon the nature and properties of the oxides and salts of iron. Iron combines with oxygen in two different proportions.† The first of these combinations is one atom oxygen with one atom iron: this is termed the first or protoxide. The second oxide consists of three atoms oxygen to two atoms iron: this is termed the peroxide, and is the highest oxide recognised by chemists. The first of these, namely, the protoxide, has such a strong attraction for oxygen, that it is nearly unknown in a pure state; but it exists in combination with some acids, such as sulphuric acid, forming the sulphate of the protoxide of iron (copperas.) When this acid is neutralized by an alkaline substance, so that the oxide is set at liberty, it immediately begins to absorb oxygen, and passes into a peroxide. This property of the protoxide of iron being kept in mind, it will enable us to explain the theory of the blue vat. When finely ground indigo is put into a vat with a mixture of lime and sulphate of iron, the first action which takes place is the decomposition of the metallic salt; the acid, which is in union with the protoxide of iron, combining with a portion of the lime, forming sulphate of lime. The detached oxide of iron extracts more oxygen from the indigo, converting it into indigogen; and the peroxide of iron thus formed, and the sulphate of lime precipitate, forming what is termed *sludge*. The remaining portion of lime seizes the indigogen, and forms with it the solution required. The following diagram represents this action and the results more clearly, and may be called the theory of the blue vat:—

* Although we have described the action of sulphuric acid upon indigo to be something different from *solution*, we use the term for convenience.

† There has been a new oxide of iron discovered lately by M. Fremy. This oxide is obtained by igniting a mixture of potash and peroxide of iron; a brown mass is the result, which, by digestion in water, gives a beautiful violet-red coloured solution. The compound is very soluble in water. A large quantity of water decomposes it in course of time. But it becomes insoluble in very alkaline water, forming a brown precipitate, which readily dissolves in pure water, and affords a fine purple-coloured solution. A temperature of 212° dissolves it immediately; all organic substances decompose it, and hence it is impossible to filter the solution. It is impossible to isolate this compound, for when the red solution is treated by an acid, as soon as the potash is saturated, oxygen is disengaged, and peroxide of iron precipitated. If the acid be in excess, it dissolves the peroxide, and gives rise to the formation of a peroxide salt of iron. It is stated to possess a powerful dyeing principle.

| | | |
|---|---|---|
| Indigo, composed of | Indigogen | Dyeing solution. |
| | Oxygen . . | |
| 2 Copperas | Oxide of iron | |
| | Oxide of iron | Peroxide of iron |
| | Sulphuric acid | |
| | Sulphuric acid | |
| 3 Lime | Lime . . . | Sulphate of lime. |
| | Lime . . . | Sulphate of lime. |
| | Lime . . . | |

It will be observed, that the theory of the blue vat depends upon the supposition, that indigogen is indigo, with an atom less oxygen; but M. Dumas, from the results of some analysis which he made upon indigo, considers indigogen to be the blue indigo, in combination with hydrogen. According to this view of the composition of indigogen, the action which takes place in the vat will be somewhat different from that given above. When the lime combines with the acid of the copperas, the iron decomposes a portion of water combining with the oxygen, and the hydrogen combines with the indigo forming indigogen, which may be represented as follows:—

| | | |
|---|---|---|
| Indigo | Indigo . . . | Indigogen, forming Dyeing solution. |
| Water | Hydrogen . | |
| | Oxygen . . | |
| 3 Lime | Lime . . . | |
| | Lime . . . | |
| | Lime . . . | |
| 2 Copperas | Oxide of Iron | Peroxide of iron. |
| | Oxide of Iron | |
| | Sulphuric acid | Sulphate of lime. |
| | Sulphuric acid | Sulphate of lime. |

The theory is equally, if not more beautiful, than the former, but in some cases it is scarcely equally reconcileable with our chemical experience. When the goods are put into the vat, the dissolved indigogen combines with them, and when brought into contact with the air, according to the former theory, the indigogen combines with oxygen, for which it has a strong disposition, and blue indigo is formed, and remains combined with the cloth; but according to the latter theory, the blue indigo is left in combination with the cloth by the hydrogen combining with the oxygen of the atmosphere forming water. That hydrogen should combine with the free oxygen of the air, and form water so rapidly under such circumstances as mere exposure, is somewhat anomalous, but this is no reason for rejecting it. If a mixture of copperas and lime be put into a bottle with distilled water, the water is not decomposed; the lime combines with the acid, which, along with the iron, is precipitated, and if the air be completely excluded, the iron remains as a protoxide for days; indeed, the change from a protoxide to a peroxide, is so slow that a long time elapses before it is appreciable; but if indigo be added, even after the mixture has stood for some time, the action of the common vat proceeds. This, according to Dumas' theory, gives a beautiful illustration of relative affinities. Before the indigo is introduced, the attraction of the iron for oxygen is about equal to that of the hydrogen, which holds it in combination as water, but when the indigo is introduced, although its attraction for hydrogen must be very weak, as it requires the nicest management to get that compound isolated; still it is sufficient to disturb that equilibrium with which the oxygen was held by the iron and hydrogen, giving the former the mastery. Whether the presence of an alkaline substance has any effect of inducing, if we be allowed the term, the formation of indigogen, we cannot pretend to determine; but it is never formed in the vat without the presence of some alkaline substance, which dissolves it the moment it is formed.

As sulphate of iron is the general deoxidizing agent used, and there being a good deal of prejudice amongst our brethren respecting the proper qualities of that substance, we shall offer a few suggestions upon the proper choice of copperas. If a piece of iron be put into dilute sulphuric acid, it dissolves with the evolution of hydrogen gas. This solution being evaporated till a pellicle or sort of skin appears on its surface, and set aside to cool, a great quantity of green coloured crystals are deposited. These crystals are copperas; but the greater part of sulphate of iron used in the arts is prepared by a different process. Sulphuret of iron, or iron pyrites, is a mineral found very abundantly in some parts in the coal measures, along with coaly matter and clay. When these materials are exposed to the action of the atmosphere and moisture, the pyrites absorbs oxygen, and the sulphur becomes converted into sulphuric acid; this attacks the iron, and also the alumina of the clay. These sulphates are dissolved with water, which drains through into beds prepared for the purpose, and the liquor is afterwards evaporated to the proper extent, so as to allow the sulphate of iron to crystallize.* Iron is sometimes added to the solution, which takes up any free acid and separates some impurities such as copper. By adding sulphate of potash to the supernatant liquor, alum is formed. Sulphate of iron is found to be composed of one proportion of sulphuric acid, and one of oxide of iron, and crystallizes with seven atoms of water. It loses six of these atoms of water if exposed to a heat of 238° Fah. This is the description generally given in chemical books of this salt; but the dyers know from experience, that there are varieties of copperas, whatever may constitute the difference of composition. Bandsdorff in the *Records of Science*, states, "that there are three varieties of the protosulphate of iron; the first greenish blue, formed from an acid solution free from peroxide; the second dirty green, from a neutral solution without peroxide; and the last emerald green, from a solution impregnated with peroxide salt." This we know by experience to be correct—that answering the description of his second variety being the best for general use. The selection of this particular quality of copperas has led the dyers into a fatal prejudice. Sulphate of iron crystallized from a neutral solution, if kept any time assumes a rusty appearance by absorbing oxygen, and converting the iron into a peroxide. Now, good copperas having generally this appearance, especially on the surface of the cask when opened, the dyers, most of them, are of the opinion that it is to this redness it owes its superior quality. But from the description already given of the nature of the vat, it will be obvious that all that is red is useless, nay worse, for it adds to the sediment in the vat. And besides this, Parkes mentions in his chemical essays, that some unprincipled dealers take advantage of this prejudice of the dyers, to sprinkle powdered lime on the top of the cask to peroxidise the surface, and make them believe that they have got a lot of excellent old copperas.

It may still be inquired what constitutes the difference of these varieties of sulphate of iron alluded to? We are sorry to say that we cannot give a decided answer to this inquiry, but will merely mention the results of our own experience relative to the question. Our first method for ascertaining the real value of copperas, was by taking a weighed quantity, generally twenty grains, of the salt, dissolving it in distilled water; boiling the solution, with the addition of a few drops of pure nitric acid, to peroxidize the iron which was precipitated by adding an excess of ammonia. The precipitate was placed upon a filter, thoroughly washed and dryed. The peroxide of iron was then carefully weighed, and noted. The average results of these trials were as 21 to 24, that is 21 pounds of good *old copperas*, as dyers term it, were equal to 24 pounds of new copperas. These results corresponded with the practical effects experienced in working the vats; but the mere extra quantity of copperas, necessary to keep the vats in working condition, when this bad stuff is used, is not the worst. It is also necessary, under these circumstances, to add an extra quantity of lime, which, in technical language, causes the vats to *swim;* that is, the precipitate swims, and is long of settling to the bottom—the goods come in contact with it, and the colour is deadened. Under this emergency the dyer uses a little carbonate of soda or potash, which forms soluble salts, and causes no extra precipitation. In order to ascertain the true amount of this evil, by a direct experiment, the writer took a solution of nitrate of barytes, in the common alkalimeter, at such a strength that one graduation of the alkalimeter exactly precipitated the acid of one grain of the best copperas. The average difference found by this method of experimenting, was as 20 to 21; and experience taught that, for every 15 pounds of bad copperas, 2 pounds extra lime had to be added. It was probably the result of such experience which led dyers to suppose that there was a bisulphate of the protoxide of iron, and to give instructions how to guard against it.†

* English copperas is often prepared from pyrites. Where there is no clay present, the excess of acid is taken up by adding iron. See an excellent essay upon the manufacture of copperas in the *Chemist*, Vol. II., 1841.

† Cooper's Treatise on Practical Dyeing.

As this watery-looking, whitish, blue, green, eopperas, is, according to Bandsdorff, crystallized from an aeid solution, it is probable that the extra proportion of acid which is found in it is owing to a portion of the mother liquor being mechanically combined with the crystals, but not forming an essential ingredient in the composition of the salt.

It may be observed that the experiments we have detailed favour the idea of the bad eopperas being a bisulphate of iron, seeing that a given weight of the one has less iron and more acid than the same weight of the other. But, it has been already noticed that sulphate of iron crystallizes with seven atoms of water. Is this quantity of water, we would ask, invariable? The green eolour of the salt depends upon the presence of water, for when deprived of its water it is white; now the eolours of the two kinds of copperas referred to are decidedly different, as already described. May it not, therefore, be inferred that the differenee of eolour depends upon different proportions of water present in the crystals, which, if this be the ease, will account for the different proportions of iron found in the same weight of the salt? It has been already notieed, that of the seven proportions of water whieh copperas eontains, it loses six at 238°, but it retains one even at 535°. We took 20 grains of each of the good and bad qualities of copperas, redueed them to coarse powder, and submitted them to a heat of between 350 and 400°, for fifteen minutes; and taking the mean of three experiments, the bad eopperas lost $1\frac{1}{2}$ grains more than the other. Although these results were very satisfactory, in so far as they agree very nearly with our other experiments, and exactly coincide with our practical experienee, yet, as the results have not been noticed so far as we are aware by ehemists who have written upon the subject, it is with some diffidenee that we give them publicity, and for the same reason refrain from offering any other remarks on the subject than will already be inferred; namely, that the whitish blue eopperas ought to be avoided in dying blues by means of the blue vat. We will probably recur to this subject in another paper, and, meanwhile, will point out some impurities which occasionally exist in eopperas, and which are very hurtful in the blue vat. A very eommon impurity in sulphate of iron, is sulphate of alumina. The deleterious nature of this salt does not consist in its action upon the indigo, but it introduces to the vat a good portion of sulphuric acid; and as it forms a double salt with the sulphate of iron—which double salt eombines with 24 equivalents of water—its presence may account for the various results obtained in the experiments detailed above, with bad copperas, and its evil effects in the vat. It is, no doubt, the presenee of sulphate of alumina that renders our Scotch copperas so much inferior to the English. The presenee of alumina may be detected by its giving the peroxide of iron, when precipitated, as already described, by ammonia and filtered, a very bulky and elayey appearance. If this precipitate be dissolved in muriatic aeid, and the iron again precipitated by eaustic, potash, added in excess, and filtered; the alumina being now in solution passes through the filter, and may be again precipitated by adding ammonia. It is a bulky white precipitate. The presenee of sulphate of zinc and copper, may be detected by a similar process—the iron being peroxidised and precipitated by ammonia. If copper be present the supernatant liquor has a blue eolour; it may also be detected by putting a piece of elean iron in the eopperas—the eopper is deposited in the metallic state on the iron. If zinc be present, and a stream of sulphuretted hydrogen gas passed through the clear filtered liquor, a white precipitate is obtained. This latter substance is very seldom present in copperas. The deleterious effects of these two substances are of the same nature; they hold their oxygen by a comparatively feeble attraction, so that when any deoxidising substanee eomes in eontact with them they yield their oxygen to it, consequently their presence in the blue vat neutralizes the effects of the sulphate of iron. It is from this property that these salts are used in resist-work, which is conducted in the following manner:—A certain preparation, the best we believe, is the sulphate of copper or zine, is mixed either with flour paste, with gum, or with pipe-clay and gum, is printed on the calico, of any pattern that may be desired; when this is sufficiently dry, the goods are then dyed in the blue vat, those parts of the piece which are printed with the copper or zinc will not be dyed blue, because the deoxidised indigo becomes oxygenated the moment it touches the copper, by its yielding its oxygen to the indigo, and occasions it to become insoluble, and eonsequently incapable of forming a dye. According to Dumas' theory, the hydrogen, in eombination with the indigo, unites with the oxygen of the copper and forms water, and both results are alike.

Before concluding this article, we may inform the general reader that, in print-works and dye-houses, where piece-goods are dyed blue, the vats are neeessarily large, being generally about 3 feet wide by 5 feet long, and 8 feet deep, made of iron, but sometimes of stone—these are sunk into the ground about half their depth. The goods to be dyed are stretched upon a frame, when the whole is lowered into the vat. Sometimes these frames are furnished with rollers, when, instead of fixing the piece on hooks, it is passed over these rollers while in the vat, by which means long pieces are dyed perfectly even in colour.

The vats for yarn or skein are small, being generally old wine or oil pipes; these are also sunk about half their depth into the ground. Wooden pins are put through the skein, and rest upon the edge of the vat, the skein is then turned over, the one half dipping in the liquor, the other half over the pins. The time of this operation varies aceording to the strength of the vat. The operation being continued some time, the skein is taken out, wrung, and exposed to the air, dipped again, and so on, by alternately dipping and exposing, till the requisite shade is obtained.

To prepare the vat, it is filled to within a few inches of the mouth with water, the dyeing ingredients are then added—the proportions given in most ehemical books, are 1 part (by weight) indigo, 2 parts sulphate of iron, and 3 lime, but this proportion of lime is too much; the practieal dyer does not eonsider his vats in good eondition when this proportion is used. The following proportions are eonsidered good for preparing one of these small vats: assuming all the ingredients good. 8 pounds of indigo, 14 pounds of eopperas, and from 18 to 20 (not above 20,) of lime. If the eopperas be bad, a pound or even 2 pounds more of it may be required along with 2 or 3 additional pounds of lime, to have the same results. These ingredients being put in, the whole is well stirred every 2 or 3 hours during the day, and, after settling for 12 hours, it is ready for use. We have been somewhat brief with this deseription, as we will probably have to give a chapter upon the manipulations of the dye-house in another part of the series.

## DOMESTIC MEDICINE.

### CHAPTER VI.

#### ON THE EFFECTS OF PARTICULAR TRADES AND PROFESSIONS AS CAUSES OF DISEASE.

It is well known that particular trades and professions—from subjecting those engaged in them to the injurious effects of exposure to the inclemency of the weather, to impure air, to want of sufficient exercise, or to over-exertion—exert an influence in the production of disease, in the shortening of life, and in the deterioration of the human race. It is also very obvious that these effects are the more or less certain and striking, in proportion as the individuals exposed to their causes have, or have not, arrived at mature age and strength.

Take, for example, the young and immature horse or ox, and, instead of allowing him to roam idly over the green fields till he has arrived at full maturity—till his muscular system be sufficiently developed,—confine him to the impure air of a stable, train him and subject him to constant hard work, feed him upon dry food, such as is fit for mature animals, and what is the result? An animal treated in such a manner will never arrive at his natural growth and strength. He will become more or less deformed; his value and his usefulness as a working animal will be greatly diminished, and his life will be mueh shortened: it is proved, indeed, both by experiment and observation, that horses, in this and several other countries of Europe, from bad treatment, and from being too early and too hard worked, scarcely ever arrive at half the term of their natural lives.

In this respect there is a elose analogy between the inferior animals and man. Manual labour is the result of muscular exertion; and strong or continued muscular exertion

can only be accomplished with ease, and without either temporary or permanent injury, when the muscular system has become maturely developed, and as long as it is properly nourished and continues in full health and vigour. In the muscular or fleshy part of the body lies the strength of the individual; and as reasonably might we expect a bunch of green flax, while bursting into flower in the open field, to equal the ship's cable in strength, as that the weak muscles and slender sinews of a raw, growing youth could endure, without injury, that continued and powerful exertion which is required of mature age.

To the young of all animals (and man is no exception), not merely exercise, but a great deal of exercise, is certainly indispensable; but this exercise must be without any sort of constraint—it must be absolute liberty to run or to walk, to sit or to stand, to lie down or to rise up at pleasure. Based on a very insecure foundation, therefore, is that system of social life, which renders it necessary that boys and girls of tender age should be immured from morning to night in the school-room or factory prison—should be compelled to debilitate their constitutions, deform their bodies, and shorten their lives, by confinement in a constrained position, and in the impure atmosphere of schools or workshops for six or eight hours a-day. In manufactories, at least, the result of such a state of things must be,—from over-exertion, from breathing air saturated with animal and vegetable particles, and from the moral contamination which surrounds them,—a race of human beings gradually sinking in the scale of intellectuality, of virtue, and of physical strength. Instead of benefiting by parental example—instead of having their bodies and minds invigorated by exercise in the open air, young children are sent to factories and workshops, where, properly speaking, they have no moral restraint—where they generally grow up slaves to the worst passions, and where the self-denial imposed by the rules of civilized society are utterly unknown. In such a community, the benign empire of reason and of religion gives way by degrees to the tyrannical sway of passion, brutality, and vice! If those who have the power in this country do not exert themselves more to have moral principle and instruction instilled into the minds of the rising generation, and if they do not, by the influence of example and every other means, endeavour to rescue the masses from that state of vice, misery, crime, and irreligion into which they are rapidly falling, the melancholy truths stare us in the face, that our nation has passed the meridian of its glory—that civilization is only another name for a refinement in moral depravity—that individual dishonesty, general corruption, and religious hypocrisy, are the means by which the great end of self-aggrandizement is to be accomplished—and that the virtues of self-restraint, Christian charity, honest and honourable dealing, are so rarely to be met with, as to show clearly that the truths of Christianity have lost their hold upon the public mind, and that, practically, the nation is steeped in infidelity.

The mass of evidence, collected by Parliament on various occasions, abundantly proves, that children employed in manufactories become deformed, stunted in growth, and totally incapable of such mental exertion as to make even a fair progress in the rudiments of education. The evidence of the late celebrated surgeon, Sir Astley Cooper, before a Parliamentary committee, is supported by the statements of the late Sir Gilbert Blane and Sir Anthony Carlisle, both eminent authorities: it is in complete accordance with the views above expressed, and does not even allow such latitude as the late Dr. Baillie, who says, "that seven years old is perhaps the earliest age at which children should be employed in factories; and, for the first year, they should not be employed more than four or five hours a-day; for the two succeeding years, six or seven hours a-day; afterwards, they might be employed ten hours a-day; and beyond that, in my opinion, there ought to be no increase of labour."

The objections here urged against the confinement of children in factories and workshops are equally valid against over-confinement in school. Children in school have not over-exertion of the body, but they have over-exertion of the mind, which is even worse; and when to this are added, the constrained position in which they must sit, the noxious influence of an impure and over-heated atmosphere, and the want of sufficient exercise in the open air, a strong constitution is thus very generally impaired, and children of weak constitutions are extremely liable to curvature of the spine, scrofula, or consumption, and various other maladies, which wither in the bud the most tender and choice flowers of our species, and hurry them to an early grave.

But supposing the period of mature age and strength to have been reached, particular trades and professions are more or less liable to induce peculiar diseases, although, as already stated, not nearly so speedily, so obviously, nor so fatally, as before that period.

These diseases arise, as above-mentioned, from four different causes:—

I.—From exposure to the inclemency of the weather.
II.—From breathing an impure and confined atmosphere.
III.—From want of sufficient exercise in the open air.
IV.—From over-exertion of the body or mind.

*First.* We have already treated the subject of the *vicissitudes of temperature*, as a cause of disease, so fully, that it is merely necessary here to enumerate a few of those trades which suffer most from this agency. Those whose employment is, in a great measure, out of doors, such as day-labourers, farm-servants, gardeners, fishermen, shepherds, coachmen, railway-guards, &c., are, of course, much exposed to the inclemency of the weather; and were it not that their vital powers are greatly fortified by habit, by exercise in the open air, and by constantly breathing a pure atmosphere, they would be infinitely more liable than they are, to be affected by those diseases to which atmospheric vicissitudes give rise; while blacksmiths, glass-blowers, brass and iron-founders, firemen of steam-engines, bakers, cooks, brewers, &c., are all, from the peculiar nature of their occupations, deprived of those counteracting influences, and as well from imprudent exposure to cold air, as from using cold drinks while their bodies are cooling after being greatly over-heated, they frequently suffer from inflammation of some of the internal organs, and from rheumatism, catarrhs, asthma, dropsy, &c.

To guard against the dangers arising from sudden changes of the weather, those whose occupations compel them to expose themselves, ought all to wear flannel next the skin; to have it changed when drenched with wet or perspiration, so as to prevent the effects of cold, and, for the sake of health and cleanliness, to have it renewed at least weekly. They ought, moreover, to have oil-cloth or water-proof cloaks or great-coats, not for the purpose of wearing constantly (being injurious to the health, by preventing the insensible perspiration from passing off from the body), but always ready at hand to protect them from rain. Those who must expose themselves to high temperatures, ought also to wear flannel; to have it renewed, if possible, twice a-week; to avoid cold drinks or sudden exposure to cold, unless the bodily heat be kept up by active exercise or additional clothing.

*Secondly.* Allusion has been often made already to the noxious effects upon individuals generally, arising from breathing an atmosphere contaminated with animal or vegetable effluvia, resulting from overcrowding, and living in small, filthy, and ill-ventilated apartments; and, in reference to this cause of disease, we have only now to mention, that those confined in the over-heated and impure atmosphere of factories and workshops are peculiarly liable to the hurtful influence which it exerts upon the human constitution. To dispel every doubt as to the truth of our assertion, we need merely point to a comparison between the strong, muscular, fresh, and healthy-looking farmer, farm-servant, day-labourer, shepherd, or sailor, and the slender, diminutive, and sickly-looking factory-lad, weaver, shoemaker, tailor, or any other tradesman exposed to the debilitating influence of impure air. These effects, however, must not be entirely ascribed to this cause. Other, and even more powerful causes must be taken into account: the chief of which are over-stimu-

lating food and the want of proper exercise. But by far the most potent of all causes is *intemperance*, in its widest signification, by which is meant not merely the abuse of ardent spirits, but indulgence in all the animal passions.

The bad effects of impure air in manufactories and workshops might be very much mitigated, if not entirely removed, by proper attention on the part of the masters to have their rooms large, lofty, and well lighted; by paying particular attention to the laws of ventilation,—remembering that impure and heated air always ascends to the top of the apartment, and gradually accumulates in the room, while the fresh air is partly consumed and partly displaced and sent up the chimney, that the opening of windows will never completely remedy the evil, for in this case fresh air rushes in, falls down to the bottom of the room, and is then carried up the vent, with but very partial benefit to the inmates. No room, in which pure air is quickly consumed, can be thoroughly ventilated without an opening for the exit of the impure and heated air; and this is most effectually accomplished by the use of a ventilator, with a delicate valve, introduced into a hole made into the chimney near the roof of the apartment, by which a current of vitiated air from the top of the room is carried up the flue with the smoke from the fire. In a room in which there is no fire, nor even a chimney, there is the more necessity for a ventilator near the roof of the apartment, communicating with the external air.

In addition to the bad effects of impure air, some artisans, from the peculiar nature of their occupations, suffer more or less severely from breathing air filled with metallic, mineral, or earthy particles, and this cause of disease is more difficult to obviate.

The workers in quicksilver mines, glass-platers, gilders of buttons, toys, &c., are affected by inhaling the fumes of *mercury*, and are liable to mercurial palsy, ulcerations of the mouth and throat, eruptions on the skin, and painful rheumatic affections of the joints and limbs, after exposure to cold. These injurious effects are fearfully aggravated by the intemperate habits of those exposed to such a cause; they often find temporary relief from their ailments in a glass of ardent spirits, and, without thinking that these evils will, on that very account, return with redoubled violence, they indulge in a remedy which becomes their ruin,—thus aggravating their primary malady, and either rendering themselves unable to follow their occupations, or hurrying themselves to a premature grave. By frequent ablutions, particularly before meals; by frequent changes of clothing; by avoiding to touch the metal with the naked hand; by carefully guarding against inhaling the fumes; by having stoves placed in such a manner as to carry them up the flue in a brisk current of air; by strict *temperance;* and by having recourse to medical aid before it be too late, the diseases arising from this cause may be in a great measure prevented.

The workmen employed in *lead* mines, plumbers, glaziers, painters, colour-grinders, type-founders, printers, and all those whose occupations require them to handle lead, or any of its preparations, or to inhale its fumes, suffer severely from colic—known by the name of *painter's* or *lead colic*,—from a peculiar species of palsy, and from other diseases which are thus induced, so as frequently to lead to fatal results. Dr. Fothergill attributes many of the diseases of children to their being permitted to play with painted toys, thus swallowing the lead which enters into the composition of paint; young artists are also liable to suffer from the same cause, from sucking their pencils. The means of preventing the bad effects arising from lead, are very similar to those above recommended to those exposed to the fumes and to the handling of mercury. The strictest attention to personal cleanliness—frequent changes of clothing and frequent ablution—avoiding going to work with an empty stomach—never using sour beer or other acid drinks—using fat meat—and, on the occurrence of any symptoms of colic, leaving off work and taking laxative medicine,—are all directions which are absolutely necessary to be attended to by those who wish to preserve their health unaffected by the hurtful influences to which they are exposed by their employment.

Dry-grinders and needle-pointers—edge-tool, gun-barrel, and other grinders—iron, brass, and other metal filers,—all suffer to a great degree; but particularly the class first-mentioned, from inhaling into the lungs and air-passages, the fine particles of metal which are so apt to give rise to inflammation and ulceration of these parts. This class of artisans are, for the most part, short-lived: they generally fall victims to consumption at from thirty-five to forty years of age. Many different plans were formerly adopted to mitigate the evil effects arising from this cause, among which the wearing of a veil of damp crape over the face was the best. But none of the expedients resorted to were of much use, till the invention of Mr. Abrahams of Sheffield was put in practice, in which the principle of magnetic attraction is taken advantage of to remove the small particles of metal from the air, thus rendering it innocuous to the respiratory organs. This invention is of the greatest consequence, and answers the purpose admirably.

Flax-dressers, pearl and horn button-makers; millers and stone-cutters; wool-carders, feather-dressers, and quill-manufacturers; sawyers, turners, weavers, and starch-makers; maltsters and bakers,—all suffer more or less from the air which they breathe being filled with vegetable, animal, mineral, or earthy particles. They are, consequently, very liable to slow inflammatory affections of the lungs, air-passages, and stomach, producing coughs, asthma, and indigestion; they are pale and sickly-looking; and, if addicted to intemperate habits, they are generally short-lived—dying of consumption, or some other disease of the lungs. For the prevention of these effects, a respirator or damp crape has been recommended, and probably with advantage, if these tradespeople were at the trouble to wear it. Wet or moistened woollen curtains, suspended over the heads of the workmen in such a way as to be agitated through the air of the place, have also been mentioned as of use; but the most effectual means, if practicable, would be to have a current of air passing through the apartment, and entering the flue near the ceiling, by which means all the fine particles floating in the air would be carried off. In addition to these measures, strict personal cleanliness, temperance, nourishing diet, and as much exercise in the open air as possible, ought, if these individuals have any regard for their health and comfort, to be carefully and assiduously observed.

*Thirdly.* Want of sufficient exercise is generally so inseparable from the other causes of disease peculiarly affecting various trades and professions, that it is difficult to know what share of the evil we ought to attribute to this cause. We know, however, for certain, that deficient exercise exerts a powerful influence in predisposing an individual to very many diseases, by inducing weakness of the muscular powers and depression of the vital energies, and by being the primary source of indigestion and all its train of woes.

"By the sweat of thy brow shalt thou eat thy bread," was part of the original curse which man brought upon himself by his fall. A law was thus imposed upon his physical constitution, which was to compel him, in all time coming, either to obey the injunction implied in this primary curse, or to suffer the pains and penalties attached to its infringement. How beautifully in this, as in everything else, does the sacred record harmonise with true science and philosophy! The scriptures tell us that we are doomed to labour for our daily bread, and science and philosophy prove that unless we do submit to bodily labour, or *exercise*, which is the same thing, we must suffer pain and disease both in body and mind, which are the penalties attached to the infringement of this great law. Exercise is indispensable, not only to preserve the body in health, but equally necessary for our comfort and happiness, and for the preservation of an active and vigorous condition of the mental faculties. Is the body or mind weakened after any illness? Gentle exercise in the open air is immediately recommended. Does a person of sedentary habits complain of languor, headache, indigestion, loss of appetite, stomach-ache, &c.? More exercise is seen to be necessary, and is prescribed with the utmost confidence even by those who have no pretensions to medical skill.

Literary men, in particular, who have no occupation to induce them to take exercise, suffer severely from this cause, and many, no doubt, would impart a little more freshness and vigour to their compositions, if they paid more attention to their bodily health; they ought to remember, that strength and vivacity of intellect are incompatible with bodily languor and debility.

Writers, clerks, and all those tradesmen whose occupations oblige them to lead sedentary lives, such as tailors, seamstresses, shoemakers, watchmakers, jewellers, weavers, &c., are all more or less subject to indigestion, accompanied with headache, pain in the stomach, bad taste in the mouth, particularly in the morning, nervous palpitations of the heart, constipation, piles, &c.,—symptoms which may end in diseases of the bladder or kidneys, consumption of the lungs, diseases of the heart, stomach, or liver. When, in addition to the long-continued sitting posture, the body is bent forward and the legs squeezed into the most unnatural position, so as to obstruct the circulation of the blood, as in the case of tailors, or pressure is made upon the chest and pit of the stomach, as in the case of shoemakers and weavers; and when to these injurious influences we add the bad effects of impure air, of too stimulating food on the one hand, and deficiency of food on the other, and of *intemperance*, we need be at no loss to account for the weak constitutions, the premature old age, and the multifarious diseases to which the majority of these individuals are liable; our only difficulty is in ascribing to each particular cause its proper share of the mischief. A strict investigation of this question leads to the conclusion, that impure air and deficient exercise, as causes of disease, are thrown into the shade when they are compared to the overwhelming influence of habitual excesses of any kind, but particularly in the abuse of ardent spirits.

For invalids, and persons of weakly constitutions, whose strength is unequal to walking a sufficient distance, equestrian exercise is peculiarly adapted; for the aged and debilitated, riding in a carriage must be resorted to by those who can afford the means; but for a person of ordinary strength, even although aged, *walking* is unquestionably the best of all the different kinds of exercise which can be tried by people of sedentary occupations. Walking sets the whole muscular system in action, stimulates the circulation of the blood, thus promoting digestion, nutrition, and respiration; and it not only rouses the dormant faculties of the body, but, by the change of scene which it occasions, it also invigorates the mind; it imparts to the cold extremities of the dyspeptic the warm glow of health, and to the desponding mind of the hypochondriac, especially if combined with cheerful conversation, the buoyancy and elasticity of youth. Not a day should pass without a certain amount of exercise in the open air, be the weather of what sort it may. If cold, exercise will produce an agreeable warmth over the whole body; if wet, recourse must be had to waterproof clothing. A walk of *four* miles is the minimum amount of daily exercise which should be taken by every individual in a state of health.—"I consider it an indispensable law of longevity," says Hufeland, "that one should exercise at least an hour every day in the open air. The most healthful time is before meals, or from three to four hours after."

"By walking four miles," says one, "I am so completely exhausted, as to be perfectly useless for the rest of the day. I return drenched with perspiration, and when I sit down I feel cold and shivering, so that, instead of receiving benefit, I am much worse for my pains and loss of time." "I could never afford the loss of an hour a-day for exercise," says another, "business, household or professional duties, must be attended to; besides, I have quite enough of exercise at these, so that I don't require to take additional exercise." "I have no inducement to walk," says a third; "unless the mind go along with the body, exercise is of no use: it is the dullest thing in the world to go out and walk for the sake of walking."

To the first we answer—*take it by degrees.* Hercules of old could never have carried the bull, had he not commenced his labour by carrying the calf: walk a mile daily for the first week, two miles a-day for the second, three for the third, and so on. The limbs will thus become gradually invigorated and habituated to the exercise, and in the course of a few months an individual will not feel half so exhausted and fatigued by walking six miles at a stretch, as he would have previously done by a walk of a couple of miles. To any one possessed of the least knowledge of physiology, it will by no means appear strange that a small amount of a kind of exercise to which a person is unaccustomed should be followed by fatigue. A set of muscles is thus brought into play, the use of which has been in a manner lost by long disuetude; and if this new action be continued for any length of time, the same effect will be produced as if these muscles had all received a strain more or less severe; the individual will feel for a few days as if he had been crushed under a heavy weight, from the effects of which he will take some time to recover. This is well exemplified in a person who betakes himself to manual labour quite unaccustomed to this sort of exercise; an hour's hard digging in a garden, for instance, will make him feel the effects in his arms and body for several days. Why be surprised, then, that the limbs, &c., should at first suffer in the same manner in those unaccustomed to walking? *Exercise strengthens the body only by degrees.*

To the second objection we answer, that neither professional, friendly, nor business visits, nor household duties, can be called *exercise,* in the proper sense of the term. They are all more or less irksome and anxious; they are attended with fatigue and exhaustion of both body and mind, but totally wanting in that change of thought, change of scene, and exhilarating muscular action, which is derived from proper exercise in the open air. Besides, to spend the necessary time in exercise, is actually a *gain* instead of a *loss* of time. Although tolerable health may be enjoyed by some without exercise, the number of years in which a man can attend to business, by abstaining from exercise and confining himself too closely, is undoubtedly diminished. The bodily machine is fabricated to endure a certain amount of the "tear and wear" of life. If this machine be kept constantly going—if it be not kept in good repair—if the wheels be not oiled—it cannot be expected to last so long as it would do with proper care. *Exercise,* then, is the *oil* to the wheels by which the human mechanism is kept in good working order, by which undue friction is prevented, and by which the machine is enabled to run more smoothly, and to continue running for a much longer period.

To the last objection we would reply, that it is very true, that if the *mind* be left behind, and be engrossed in the duties and cares of the "world at home," it is a useless waste of time for the body to walk. What enables the sportsman, unaccustomed to exercise, and habituated to ease and luxury, to rise with the sun, and undergo the most laborious exercise, without the least fatigue? What makes the great difference between the exercise enjoyed by a pleasant excursion in the country, and the labour undergone by a necessary and monotonous round of professional or business visits in town? What makes a child endure an amount of exercise at his plays, which would overpower him with fatigue by walking half the distance on a public road? It is *mind,* in which lies the great secret of beneficial exercise. Take a cheerful, intelligent, and congenial friend to accompany you in your exercise, or study some pleasing branch of natural science, as botany or mineralogy, and go and collect specimens; have some pleasant object in view by your walking, such as paying a visit to a friend at some distance; or, finally, if you can do no better, have your residence some way off from your place of business, so as to force you to walk: in short, every one ought to contrive by some means to interest and occupy the mind, so as to abstract it from the anxieties of business and the turmoils of life; and in our opinion this can be best accomplished by the choice of a suitable companion in our walks—for man is a *social* animal.

The last remark we have to make on this subject is, that unless the weather be very cold, or the individual very weak,

no one ought to put on additional clothing before setting out; indeed, fewer clothes should be worn, to make walking exercise fulfil the end intended, than is necessary in-doors; and, above all, every one ought to be free and untrammelled by tight dress (such as tight stays, tight shoes, and all other abominations), and the animal temperature should be kept up by as brisk walking as the individual can endure without injury—for, to *saunter along* is no exercise.

*Fourthly.* Over-exertion of the mind and of the body is the only remaining cause of disease which we have to notice, as affecting individuals of particular professions and trades. It is well known to physicians, that an excess of mental exercise is a much more powerful cause of disease than over-exertion of the body; that literary men, and all who indulge in too severe study, are subject to melancholy or hypochondriasis, paralysis, apoplexy, inflammation of the brain and its membranes, mania or softening of the brain. No doubt the causes to which we have already alluded—want of exercise in the open air, exposure to the impure atmosphere of their apartments, and the constrained position of their bodies—contribute their share to the production of the evil; but over-exertion of the brain, producing a determination of blood to the head, is the chief cause. To all these causes put together, may be ascribed the ruined constitution or the death of many a promising student, who, aspiring with ardent zeal to academical or literary distinction, wastes his bodily and his mental energies over the midnight lamp, and blasts the hopes of fond friends and admiring companions. We can, in the same way, account for the melancholy wrecks which now and then occur of the finest and most powerful minds that ever adorned the literature of a country; the cords of the intellect, from long-continued over-stretching, become paralysed—in a fatal hour the tension is increased—they burst asunder, never to be reunited!

Over-exertion of the body is productive of disease among labourers and certain classes of tradesmen, such as porters, coal-heavers, draymen, blacksmiths, miners, &c.; and it tends very much not only to shorten life, by gradually exhausting all the vital powers, but may immediately give rise to hernia or rupture, disease of the heart and blood-vessels, spitting and vomiting of blood, bleeding from the nose, sprains, &c.; and, if the bodily strength be not kept up to the maximum of vigour by a sufficient supply of good nourishing food, the bad effects arising from this cause will, of course, be proportionally increased. Over-exertion of any particular part of the body, independently of its injurious action on the general frame, is certain, sooner or later, to produce disease in that part. For example, over-exertion of the vocal organs, as in the case of singers or public speakers, gives rise to disease of these organs, and of the windpipe, lungs, and heart. Engravers, watchmakers, embroiderers, painters, tailors, workers at iron forges and furnaces, &c., are all liable, from over-exertion of the eyes, to short-sightedness, inflammation of some of the structures of the eye-ball, and even total loss of sight.

Some workmen, again, are obliged, from the peculiar nature of their occupation, to keep their bodies in a confined position, as tailors and shoemakers, and particularly miners and colliers, who are, moreover, much excluded from light and air; they are, consequently, from defective nutrition, generally spare men, with curvature of the spine and bow-legs; they have a sallow and unhealthy complexion, and seldom live beyond middle age. By proper attention, however, to the great laws of health—sufficient exercise in the open air, great personal cleanliness, nourishing diet, temperance, the careful ventilation of their workshops, &c.,—most of these bad effects are capable of being greatly mitigated, if not completely removed.

Thus we see that the very means by which millions of our fellow-creatures are obliged to earn their daily bread, are so many causes of disease—that the cup which contains the balm of life, also conveys the secret poison—contributing to shorten the natural period of man's existence, and to fill even that diminished period with misery and pain! How is this? Is it a sin for a man to be poor, and to be obliged to adopt a trade or a profession with which health, happiness, and long life are incompatible? And is he, for this poverty, to be punished with misery, suffering, and affliction, for no fault of his own, but for a condition of life in which Providence has placed him? And is the millionaire, who inherits the wealthy possessions of his ancestors, to enjoy, without any merit on his part, those blessings of health and happiness, and that freedom from bodily pain and mental sorrow, which is denied to his poorer brother? Repine not, nor mourn thy lot, thou son of toil! That share of pain and misery and sorrow, which is allotted to man in this world, neither arises from his trade, nor from his profession, nor from any external circumstances over which he has no control. Man's happiness by no means depends on his amount of worldly possessions—the peasant may be happier than the prince—an increase of wealth is generally accompanied with an increase of care, annoyance, and vexation. Do not suppose that the occupants of yonder carriage, which rolls along attended by a retinue of servants in livery, are any happier than that humble pedestrian who must run out of their way to save himself from being ridden over. True happiness is neither to be found in carriages, nor in lands, nor in wealthy possessions, nor in a retinue of servants, nor in stores of gold; but is alone to be found in *a contented mind, conscious of rectitude, at peace with its God, with itself, and with the world.* The experience of thirty centuries proves that Solomon's golden mean—"neither poverty nor riches"—is the most compatible with, and the most conducive to, *this heaven upon earth.* It is in perfect accordance with the experience and observation of philosophers in every age and country, that the happiest condition of life is that in which both body and mind *must* be rationally occupied for a certain number of hours every day. Does the professional man, the mercantile man, or the tradesman, amass or acquire wealth sufficient to enable him to retire from the duties of active life, to spend the rest of his days apart from the turmoil and troubles of his profession, and to live in comfort, happiness, and ease, in the bosom of his family, in some choice and secluded rural locality? Is such an individual happier than when his mind was absorbed in business? If he choose to expose the state of his feelings, and (unless he have merely exchanged his former profession for some other rational employment which equally occupies his thoughts) if you gain his confidence, he will tell you that he has recourse to all sorts of expedients to kill time, but that still it hangs heavy on his hands—that from morning to night, and from night to morning, he is *dying with the disease of having nothing to do.*

The man of wealth—the idle man—the man of no profession—is exposed to innumerable temptations, to which the poor man, the professional man, and the tradesman are complete strangers. He is either afflicted with the cares, the anxieties, and the vexations which are almost the invariable concomitants of wealth; or, unless he be possessed of a refined and cultivated intellect, he is led to indulge in the frivolities, the vanities, the extravagances, and the debaucheries of fashionable life. Such an individual is compelled to adopt every kind of foolish substitute for rational employment; to resort to hunting, fishing, attending theatres, club-houses, assemblies; and—if a female of religious habits—to an endless round of prayer-meetings, in the vain attempt to participate in that pleasurable exercise and excitement of the body and mind, which the professional man and the labourer enjoy at their special avocations. The wealthy man is not even happy in his friendships, for he rarely discriminates between the flattering parasite and the man of sterling merit.

Mark the contrast between the above picture and the case of the professional man, the artisan, or the labourer, whose hours must be rationally occupied to enable him to support himself and his family, and whose spare hours will be devoted to his bodily and mental improvement: his time does not hang heavy on his hands—he feels no *ennui*—labour is to him a blessing; and although he may occasionally meet with annoyances connected with his business or his profession, he will rise above all such petty vexations—he will

look on the bright side of human nature; and, if misfortune overtake him, he will have the satisfaction to think that it has arisen from no fault of his own, but is merely one of the contingencies of life. If the world treat him with ingratitude, with coldness, and with neglect, he will enjoy the sweet consolation that his friends "*at home*" will never look cold: in prosperity, in adversity—in grief or gladness—in pleasure or pain—they will always share his feelings: no duplicity there; no hypocrisy, no affectation; but every look, every thought, every word, is the genuine expression of heartfelt affection. The friendship he experiences cannot be assumed for a purpose, for his friends can have no object to serve by making false pretences; they can gain nothing but a return of that true friendship which is far more sterling than gold.

In fine, the working man obeys that great law of nature, which commands him to "eat his bread by the sweat of his brow;" and, unless he break other laws equally binding, his reward shall be, health and happiness for the term of his natural life. His enjoyments are rational; those of the idle man irrational. The labour of the former, if not too severe, invigorates both his body and mind; the excesses of the latter, exhaust his vital energies and debase his intellect. Upon the labours of the former depend not only his own comfort and support, but the wealth and prosperity of a nation; while the latter contributes more, by the influence of bad example and other failings, to retard than advance both national prosperity and the civilization of mankind.

## DIAL OF THE SEASONS.

### CHAPTER II.

A DAY—THE DIURNAL REVOLUTION OF THE EARTH ON ITS AXIS.

We are living upon the earth, one of the eleven planets which revolve round our sun. Although the earth is very small in comparison with some others of the planets, being, as we have noticed in the preceding chapter, only $\frac{1}{1400}$ of the bulk of Jupiter, and is such a mere speck in comparison with the spaces of the solar system, as to be receiving only about one twenty-two hundred and fifty-six millionth of the whole sun's light; yet, compared with our feeble means of observing and exploring it, it is an orb of immense magnitude, whose parts have not yet been entirely explored, and whose varied productions seem almost infinite, so as to afford a field of investigation exhaustless to human industry. Even if, for the sake of better observation, an observer direct his especial attention to one department of nature—vegetation for instance—he could expect, during a long life, to see but a part of the variety of trees, and plants, and flowers, and mosses, which flourish in all parts of the earth.

Our notions of distance and extent are gradually acquired. The streets of a town, the fields of our father's farm, the adjoining farms, the encircling hills of our native valley, are the world which dawns upon childhood. The path to the school-house, or to a neighbour's, is perhaps the first geographical acquisition. A ride of a few miles, a day's journey, maps, books, numbers, aid in forming our earliest impressions of extent and distance. On maps, the position of our home is pointed out to us, and the divisions, rivers, and outlines of our own country. At length we begin to notice, in connection, the positions of countries and continents, and to form some idea of the globe itself. The present chapter is designed to aid us in forming a mental picture of the extent, and of the diurnal motion of the earth.

The earth is a globe about twenty-five thousand miles in circumference. One half of it is always in sunlight, the other half is not in sunlight, but in starlight. All parts of it are in starlight, but those persons who are in the sunlight do not see the stars. It is only when that part of the earth on which we are, turns into its own shadow that we can see the stars. But they are always there, and shining in the daytime, though the strong light of the sun obscures them to our vision.

The sunlight is falling vertically from the zenith but at one place, or, as mathematicians would say, one point. From this point it falls more and more obliquely on all sides till you approach the edge, where it is horizontal.

At the distance of about six thousand miles, one-fourth of the earth's circumference from the vertical point west, the sun is rising; six thousand east, the sun is setting. Also, six thousand miles north or south from this vertical ray, the sunlight is falling parallel with the earth's surface, both in the Arctic and Antarctic latitudes.

The angle at which the sunlight is falling, is the primary cause of the seasons and climates in all their varieties and vicissitudes. Its more vertical rays are constantly maintaining the glowing splendour, the exuberant vegetation, and the swarming life of the tropics, while its oblique rays are diffusing a feeble fading light on the dreary and frozen regions of the poles.

Our position at London is such, that about 3,580 miles south of us is the equator, which is the centre of the sun's influence midway between the cold poles. A similar distance north of us takes us far beyond all human habitations, and beyond all animal and vegetable life, far upon the polar ice. Our latitude is on the middle ground between the extreme heat of the vertical sun, which is always existing south of us, and the extreme cold which is present at the north. South of us, towards the equator, the forests are characterized by several hundred species of palm-trees, on which are at all times nestling thousands of species of birds of brilliant plumage. Around us are the oak-tree forests, and the scenery of the temperate latitudes. North of us are the fir-trees, the reindeer, and the Esquimaux; and beyond these, deserts of unexplored and unexplorable ice.

Every one has heard of the earth's turning round on its axis every day. The fact is universally admitted, but very few persons have an adequate idea of so vast a truth.

The earth, as it rolls round from west to east, is continually sweeping its eastern landscapes into the sunlight, while its western landscapes are proportionally receding into sunset and shadow. Thus an eternal evening and an eternal morning are perpetually present.

For the purpose of illustrating in some degree the extent, scenery, and daily motion of our earth, I shall ask you carefully to follow a very simple narrative of my own course of thought as it actually occurred.

It was the evening of a delightful midsummer day. Before me was an American landscape, familiar to my childhood's recollections.

The sun's last effulgence was lighting in tints of gold and purple the western horizon, when this simple reflection occurred to me:—He is leaving our hemisphere in darkness, but his bright rays are at this moment dawning on the other side of the earth, and illumining the landscapes of the eastern continent; the bland light of morning is breaking on the mosques of the Ottoman; the worshipers of Allah, the devotees of Mahomet, are performing their orisons; the Arabian herdsman and the Persian caravan-driver are hailing in prostrate reverence his rising beams, in worship to the god of their fathers; at this moment he is shining in meridian splendour on the vast expanse of the Pacific ocean; yet at this same moment the inhabitants of Europe are buried in the unconscious slumbers of midnight. While on this side of our revolving planet, the shadows of evening are inviting us to repose; on the opposite side the blessed light of morning is breaking the slumbers of all nature, refreshed for the renewed enjoyment of existence. Thus, morning and evening are perpetually present, and chasing each other over earth and ocean, with the astonishing velocity of a thousand miles an hour, and completing the earth's circumference in what we call a day, or in each complete revolution of the planet on its axis.

Let us gaze for a moment on the setting sun. Let us now imagine ourselves to be elevated a short convenient distance

above the earth's surface, and that the attraction of gravitation is so modified in our favour that we may remain during twenty-four hours, while the earth should roll round beneath us. Accompanying the earth in its annual, but not in its diurnal motion, we shall thus have a sunset scene all round the planet; before to-morrow evening, a bright vision of land and ocean, 24,000 miles in extent, a landscape, a living panorama, with all its human, animal, and vegetable tenants as actually co-existing, encircling the whole globe, will have passed beneath us.

In order to realize this picture, we should select some well-known position, embracing, if you please, the scenes of your infancy, or those with which you are most familiar. For example, St. Paul's, London; Arthur's Seat, Edinburgh; the spire of the Hall of Independence, Philadelphia; the cupola of the State House, Boston; the Capitol, at Washington; the Kremlin, Moscow; the cliffs of the Missouri; a cottage of the upper Alps; the peak of Teneriffe; a summit of the Andes or Himalaya—take whatever point you please.

If you leave the choice to me, however, I will select Philadelphia, my own native city.

Let us then suppose ourselves to be elevated, as before stated, around the spire of the Hall of Independence, on a fine summer evening, and that fine evening to be this present moment.

We have beneath us the actual scenery, with all its bustling residents in real life—the living panorama of the hour, with all the combined associations of society, of commerce, of childhood, and of home.

It may be proper to remark here, that the rapidity of the earth's actual rotation, seventeen miles per minute, one quarter of a mile to each second, is much too great for our purpose of attentive observation—therefore, we must suppose it to move only so fast as we may incline to proceed in the survey. The distinctness of the idea you will be able to form of the revolving picture, will of course be more or less complete, in proportion to your previous facilities of observation on men and nature, and the attention with which you have improved them.

To illustrate this by an example: In a stage-coach or car passing between Philadelphia and New York, or in a vessel gliding beneath the majestic banks of the Hudson, the Ohio, or the Rhine, every traveller passes the same scenes, and sees to a great extent the same objects, the same group of fellow-passengers; every ox in the adjacent meadows, every tree, every rock, every flower by the wayside, is pictured to the vision of all. The whole scene forms a moving daguerreotype to every eye; but the various intelligence, the contrasted pursuits, the predominating passions of each individual, direct his attention to different reflections: one notices the crops particularly, another the buildings, another the vessels; one is entranced in love's potent enchantment, another is thinking of his absent friends, others are meditating some commercial or political project, one is elate with success and hope, another is sad with the sorrows of his condition. It would require even more than the powers of the myriad-minded Skakspeare to observe, comprehensively and discriminately, the scenes of life around them. While we are noticing one thing, myriads are escaping us.

But the scene below is moving. My native city, the home of my childhood, with its spires, and the smoke of its thousand firesides, is gliding under us toward the eastern horizon, while its suburbs, the Schuylkill, with its coal-blackened wharves, its coal ships and its beautiful bridges, approach us from the west; and the farms beyond, each with its cultured fields and its domestic scenery, the ploughman whistling at his labour, or loosing his tired horses, the cattle grazing in the meadows, the poultry gathering to their roosting-place, the cows ruminating in the yard, the rosy milkmaid singing at her task, "the playful children just let loose from school."

The summit of every hill reveals to us a fresh landscape, ever-varying scenes of rural beauty, chequered with all the actual incidents and interest of the evening hour. In these delightful valleys, the descendants of the colony of Penn enjoy probably more than average contentment. We witness, however, the realities of human life: the hope-lit dreams of youth, the toil and thoughtfulness of manhood, the gambols and prattle of infancy, the follies and virtues of every age, the results of industry and indolence, of temperance and benevolence, of sensuality and of selfishness, are all before us. We see everything precisely as it is.

The beautiful village of Westchester, reposing amid delightful agriculture, the frequent succession of farms where the rivulet-sources of the Brandywine, alternately margined by exuberant woods and grassy meadows, are winding amid cultured hills where the ploughshare has half obliterated entrenchments, memorable in American revolutionary annals, give place in a few moments to ranges of more extensive valleys celebrated for their limestone fertility, and the admirable cultivation of the German settlements.

The streamlets now beneath us are those of the Conestoga. The provident industry of men, descended from one of the most industrious races in Europe, has here spread a bright and luxuriant carpet of crops over a soil of unsurpassed productiveness. The setting sun calls the happy husbandman from his labours; huge waggons groaning beneath golden sheaves, and drawn by noble horses, are everywhere tending homeward from the wheat fields, to barns of palace-like proportions.

The scene beneath us is the county of Lancaster, proverbial for its agricultural beauty and fertility. The somewhat antiquated town you notice on the right, approaching us, is Lancaster city; twenty years since, the largest inland town of the American Republic, but now far surpassed by the modern cities of the West. The simple structure of its timeworn dwellings, and the contented physiognomy of its industrious citizens, remind one of their descent from the fatherland of the Goths. That old house yonder, with the moss-covered roof, is the birth-place of Robert Fulton, and around it, beneath those trees, were the earliest scenes of his infant pastimes.

You may now observe in the horizon before us, the first smaller ridges of the Alleghany mountains; the fragrance of a thousand hay fields, the joyous song of the reaper, the measured tread of the athletic cradler, the luxuriant orchards, the groves, vocal with the evening songs of happy birds, glide rapidly onward under us.

Yonder, amid glorious amphitheatres of landscapes glowing with the benignant bounty of harvest, and studded to the hill-tops with rich barns, cottages, and luxuriant forests, is that loveliest of American rivers, the Susquehanna. There it is! coming with its forest-skirted shores and delightful islands, its cultured valleys and its bold mountains; its broad volume rushing beneath giant bridges, gleams sweetly in the placid light of evening.

Do you notice, just beyond the wood, near that half-shaded cottage on the hill-side, an old man leaning on the fence? He is an old Switzer, a patriot soldier of the Swiss cantons. His hair is thin and white. The soil on which he stands is his own. When the French eagles subjugated the liberties of his country, he left the valleys of his fathers a voluntary exile, and has here found a home for his children.

That somewhat bent figure you can just recognize, where the road winds over the hill which is approaching us, is a veteran of the army of Egypt, who, having followed the brilliant career of the First Consul, over the glaciers of St. Bernard, the vineyards of Italy and the sands of the desert, and having since survived the desolating pestilence and the bloody campaigns of St. Domingo, dwells amid these scenes of culture and solitude, musing, as did the Emperor at St. Helena, on the recollections of the past.

The town approaching us on the left is York. When, during the war of the Revolution, Philadelphia was occupied by British armies, the fathers of the Republic, by the advice of Washington, retreated to the interior, and York was for some months the scene of their councils.

Harrisburg, the finely-situated capital of Pennsylvania, passes us a few leagues to the north, too distant for accurate observation. Had our starting point been one degree of latitude further north, there would already have passed beneath us the coal regions of Eastern Pennsylvania, where the an-

thracite, in strata of extraordinary thickness, crops out on the sides of the mountains, traversed by the tributaries of the Delaware, the Lehigh, the Schuylkill, and the Susquehanna, and accumulated in the ample repositories of nature, awaits in exhaustless abundance the wants of future ages.

We have now beneath us the wild scenery of the Juniata, winding in the mountain ravines, its beautiful little valleys forming a charming contrast to the dark precipitous rocks and forest-covered solitudes. Yonder you may trace the line of the Pennsylvania canal. Those boats are laden with the products of the West. The music you hear is the horn of the boatman echoing sweetly in the wild passes before us.

The road which winds around the mountain has been cut with great labour, along frightful precipices, while far above the white-headed eagle wings his solitary way to his lofty eyrie.

The dark ranges of the mountains, clothed with gigantic forests, like a vast billowy ocean of verdure, sweep in solitary grandeur beneath us, where occasionally groups of girdled timber, stretching their storm-blanched branches towards heaven, the lonely cabin of a hunter, scarcely visible amid the blackened half-burnt stumps, and a few scattered villages at long distances in the valleys, break upon the exuberant wilderness.

It will, of course, be necessary that we should alter our elevation, as the mountains and the river sources approach us. I did not wish to trouble you, in the first place, with the details of the necessary mechanical part of your outfit, but you have attached to your shoulders a pair of wings, so contrived as to enable you gracefully, and with slight bird-like exertion, to alter your elevation at your pleasure or convenience. If you wish to examine the general surface and topography of the country, we will choose an elevation of some thousands or tens of thousands of feet, where you will find the telescope in your belt useful—when you are disposed, in our long future survey, especially to notice the inhabitants of the respective countries, the characteristics, occupations, civilization, costumes of the nations, you had better unceremoniously approach very near and salute the inhabitants; the cosmopolitan trumpet you have slung on your breast, will enable you to converse in any language, and inform yourself on every subject.

When you wish to acquaint yourself with natural history, and to examine the flowers and insects of earth's countless valleys, or the crystals or mosses of the mountain rocks, you may apply your microscope deliberately, and you will soon learn to accommodate yourself, by a mere act of volition, to all varieties of surface, raising yourself just sufficiently to allow objects to slide beneath you, now penetrating the deepest shaded ravines, now skimming the untrodden precipices of the mountains, now soaring above the clouds; and thus you will always be able to view, in its natural position and habitudes, every object at the proper distance and best adapted light. The lesson of our survey is the co-instantaneous existence of all things at this moment. We read, in books of travellers, of what appeared and happened in distant parts of the earth years ago. We are now to see and to study all things as they exist to-day, at this passing instant of time.

The actual, stupendous, quiet rotation of the planet, though too rapid for detailed observation, may be illustrated from any commanding summit. The mountain islands and the mountain coasts of ocean are visible to the mariner at the distance of one or two hundred miles. The view from the peak of Teneriffe, or the heights of Mount Olympus, is not less than one hundred and fifty miles, or three hundred miles in diameter, or one thousand miles in circuit; now, as one thousand miles an hour is the rate of the earth's rotation, an observer on these positions, directing his attention to the horizon around him, would occupy at the same rate one hour in the survey.

In like manner, an observer on an eminence commanding two and a half miles of view in every direction, which is five miles in diameter, and fifteen miles in circuit, would at the same rate be allowed one minute to survey the scenery around him.

This may be well and practically illustrated by any observer in scenes of intermediate extent, say of fifty to one hundred miles circuit, as the valley of Wyoming or of Tempe, the bay of New York or of Naples; the rate of near four seconds to a mile, or one quarter of a mile to each second, which is the actual rate, when the scene is somewhat extensive, will be found ample for all the purposes of general topographical observation of the landscape. At the distance of several miles we should see the mountains, cities, and rivers, as on a map.

The mountain air sustains a vigorous vegetation. Do you notice what a noble forest covers the summits and clings to the steep acclivities of the torrent-cleft ravines?

On the highest ranges, a giant growth of chestnut and cherry combines with the beech, the poplar, and the oak, to form masses of forest; towering above these, the tall conspicuous white pine is interspersed and often predominates, covering vast tracts of the landscape with a dark perennial shade, while the hemlock, fond of humid situations, covers with a deeper shade the precipitous glens and swampy intervals of the streams.

Look yonder, a wild cat is peeping from a hollow limb of that dead-topped white oak. In the morass of the ravine below us, the bear cools himself at mid-day, the squirrels skip among the trees, the pheasant clucks to her brood, the fawn gambols by his dam, the song-birds are singing their vesper hymns of gratitude. Where the stream eddies beneath the root of that old beech-tree, the otter is watching the trout sporting below him. 'Tis midsummer: the shad of the Chesapeake, after pursuing an industrious and devious pilgrimage from the ocean, has here arrived, conformably to the eternal instincts of his species, to pay his yearly visit, at the season when the mountain laurel blossoms by the cool fountains of the furthest Susquehanna.

Over some tracts of the mountain wilderness, the tufted foliage of the forest is grouped in ever-varying variety; in others, groves of different trees alternate with each other in masses, and contrast from afar, shading, in receding perspective, the exuberant outline of the mountains. The curvature of the summits swells in vast undulations, graceful as those of ocean, while occasionally abrupt cliffs lift themselves from the billowy verdure. Over the scene below us; at this moment, a heavy thunder shower is passing away, the sunlight is resuming its gladness, the dense clouds, sweeping in dark drifts over the showery landscape, cast their flitting shadows on the dewy, brilliant amphitheatre before us, while a glorious rainbow is reflected on the retiring shower, behind the eastern hills. Amid the vivid pea-green of the beeches and maples, you may notice those dull, green, storm-scathed summits of the old hemlocks, which have survived for many ages, and whose annals, "if there were tongues in trees," would recall the fierce ambition and the tranquil loves of many an aboriginal chieftain, ere the brave forest-destroying race of the Anglo-Saxons had dispelled the domain of the native red men o'er the proud forests of these thousand mountains.

We now look down on the hills of western Pennsylvania, traversed by deep ravines shaded by the unbroken forest, or luxuriant under far-spread cultivation.

Below us are strata which comprise the bituminous coal measures. On the north, the mountains swell in gentler undulations, and at length blend into the fertile plain which extends toward the borders of the lakes.

On the south, as you may notice, we have still present the wild and precipitous outcrop of the sandstone formations which embrace the coal strata.

Yonder, where the deep forest ravine of Turtle Creek breaks the heights of the Monongahela, moulder the bones of Braddock, with those of the wolves who feasted on his unburied soldiers: it was here that the youthful Washington saved a remnant of the army from the scalping-knife of the Indians, and the labyrinth of these awful forests.

The little forest springs, and meadow-spring-house streamlets beneath us, are sources of the easternmost tributaries of the far-draining Mississippi. You observe that the country is more cultivated, and the frequent scenes of harvest-home alternate with the masses of forest, and become the most interesting feature in the sunset landscape, till amid the high

picturesque banks of the three rivers—the flag of old Fort Pitt, and the dense smoke rolling up to heaven from the thousand furnaces and steam-power factories of Pittsburg—the canal boats and arks and bridges, and fleets of steamers from the far windings of the "father of waters,"—and now the present panorama of the city, with the noise of its tilt hammers and the hum of its people, sweeps beneath us.

The valley of the Ohio (the beautiful river, as the red men truly named it) glides on. The mellow light of evening falls enchantingly on hill and vale. Groves of the old forest, village scenery, countless successions of farms grouped with the industry of harvest, the happy homes of your own countrymen, and fair faces, on which to linger would be to love, beaming on you at intervals from their cottage doors, amid scenery beautifully diversified and everywhere bright in the rich verdure of the summer solstice, pass swiftly by. We have no time to pause. We are viewing in rapid succession the luxuriant valleys of the Muskingum and the Scioto, the Miamis and Wabash, the Kaskaskia and Illinois, where the luxuriant forest and the wandering savage, the Anglo-American hunter, and the pioneer woodsman, have given place in one generation to scores of villages and cities, abounding with the arts and luxuries of civilized life.

We are now approaching the Mississippi, above the confluence of the Missouri, that junction of mighty waters. A thousand rivers flowing toward us from every point are concentred below us. We are in the centre of a vast basin, whose rim extending behind us to the summits of the Alleghanies, and on the right to the lakes of the north, hides its rocky margin a thousand leagues before us in the clouds, and stretches far to the south toward the Gulf of Mexico.

We would fain separate, and trace back to their sources, the elements of this immeasurable aggregate of rivulets. Its eastern fountains behind us are gurgling in the dairies and mountain springs of New York and Pennsylvania, and along the forest-covered declivities of the Alleghanies, to the Carolinas. Its western tributaries are tumbling in a million of waterfalls from the broad slope of the Rocky Mountains, the moose deer is listening to its eternal cataracts in the fir-tree forests of the far north, the buffalo is drinking from its broad prairie-wandering branches of the west; let us trace back this mighty father of rivers to its countless streamlets, and observe them all busy in their pauseless course downward toward the ocean; everywhere, on its remotest streams, the canoe of the red man is still plying, and his whoop echoes at intervals in the silent forests, thousands of lovely islands are sleeping in the sunset light on its bosom, on its eastern margins are scattered the cities and village spires of the Anglo-Saxons, and snorting steamers, richly freighted, are climbing with a powerful leverage the descending course of its accumulated waters.

Let us follow up its furthest sources, in all their windings, for a thousand leagues, in the silence of the forest ravines, or the interminable prairie, till beyond, in the widening perspective, the bristling mountains lift themselves to the regions of eternal snow, and the dark lake of the cedars drinks its crystal tribute from the glaciers of the furthest Missouri; all destined, by months of diligent and tireless meandering, to the distant delta, where the lazy alligator is lounging in the stagnant bayous, and the turbid river-gulf curdles amid the blue waves of the Atlantic.

Can you embrace the territories of this mighty river, recognize its vast extent, and trace out its extremest margin-line? whence, from many a dividing summit, portions of the same snow-drift have already mingled by the Susquehanna and the St. Lawrence with the Atlantic, or have swelled the freshets of the Oregon against the surges of the Pacific ocean.

The waters of Missouri, as you may notice, are turbid with a white or ash-coloured earth, which always occurs at this season, and indicates the presence of the freshets of its upper sources. It is remarkable in the observation of the tributaries of the Mississippi, and of other rivers, that the variety of climate and of temperature, from various elevations, does much to sustain their waters during the season of summer, when the evaporation is greatest.

The sun, with the advance of spring, melts earliest the snows of the southern parallels of latitude, and brings down in February the freshet of the Red River, tinging the volume of the Mississippi with the red-coloured residuum of its waters. Two or three weeks afterwards, when this has partly subsided, the sun reclaims another latitude from the frost, and then the vast flood of the Arkansas, turbid with brownish mud, becomes the easily distinguishable and predominant mass of the mighty river. Subsequently, about the middle of March, the certain progress of the season liquefies the snows of another range of latitude, and the freshets of the Ohio and the La Platte, muddy with yellowish earth of various shades, reach the Mississippi, and replenish its waters. To these gradually succeed the waters of other and more northern tributaries, till in May the flood of the upper Mississippi arrives, bearing an uprooted forest on its surges, and tinging with blue earth the lower pilgrimage of the waters.

During all this period, the northern and more elevated sources of the Missouri remain locked in thick-ribbed ice, and contribute a cold and limpid current to the cloudy waves of the Mississippi; but about the middle of May, the snows of the furthest and most elevated sources of the Missouri yield to the vernal sun, and commencing their long pilgrimage of four thousand five hundred miles to the ocean, reach the Mississippi in June and July, colour its waters with the whitish nitrous earth with which you may now observe its current is loaded, and sustain, during midsummer, the flow of the waters when the innumerable springs of its lower valley are most diminished by intense evaporation.

This gradual release of the streams from their icy fetters is a beautiful instance of the design of Supreme Wisdom. If the sun acted on the whole basin with simultaneous power, one immense, all-destructive deluge would overwhelm the valley, and when it passed would leave the river in comparative insignificance. As it is, the rise of the waters sometimes threatens destruction, but the laws of nature limit its proud volume. The vast annual overflowings, constituted as they are of the successive irrigation of its different tributaries, are marked by corresponding successive deposits of red, of brown, of yellow, of blue, and of ash-coloured mould, on the shores and levels of the delta, and the whole alluvion of the river presents, when dug for many feet, the same curious record of the subsidings of the freshets of ages.

This nitrous impregnation of the Mississippi during summer, from the furthest sources of the Missouri, is of immense importance to the salubrity of its waters. The hardy boatmen drink its muddy sweetness in copious libations with delight; the traveller, half sick from unwholesome waters and a thousand privations, thanks the all-provident Creator when he reaches the river, and imbibes with its waters cheerfulness and health.

But I must recall you from hydrography, which is but one of a thousand studies in a view of our earth, to the more immediate observation of the scene beneath us.

We have now before us the region of those great mineral deposits, which nature has allotted to the centre of the immense valley of the Mississippi; or, to speak more geologically, the perpetual abrasion of the descending waters, wearing deep into the older underlying formations of the central continent, has here disencumbered from its superincumbent strata one of the richest mineral districts of the globe, and which, admirably situated in the concentrated ramifications of steam navigation, is destined to supply, during unknown ages, the future immense population of this mighty continent.

Those peaks you notice on our left, are of magnetic iron of excellent quality, and in quantity forming entire mountain ranges.

The white masses you see projecting on the brow of the hills, and scattered beneath us, are of white quartz, the *mineral blossom* of the lead miners.

Yonder, on the right of the forest, is one of the lead-mining villages. Observe the miners at their work. The lead ore appears very pure and beautiful.

We pass the windings of the vast and turbid Missouri, with its picturesque bluffs, where the vulture and the eagle nestle,

and below us, for hundreds of leagues, are rapidly sweeping the broad, far-watered prairies of the La Platte, mingling like the solitudes of ocean with the distant horizon; only varied at intervals by a few solitary oak-trees on the hills, and by groves of cottonwood and willow, which skirt the margins of the streams.

Observe, beneath yon bright cloud in the distance, that dark line which stretches along the horizon! 'Tis the buffalo in vast herds. See, on the left, they still seem to touch the blue of the furthest sky. What innumerable herds! What tumultuous masses! How rapidly they rush onward! You may hear the thundering of ten thousand hoofs. How fierce they seem! Yet all this running is for mere sport.

The buffalos are passed, and the broad, silent, solitary prairie is again fleeting beneath us. How splendid those sunset clouds are, just at this moment! Look, on your right are buffalos again. An immense herd at rest; they are ruminating as quietly as oxen.

Do you notice that drove of white animals? They are white wolves. They accompany the herds of buffalo in a playful and friendly way, until a buffalo, weaker than the rest, has the misfortune to become mired in crossing a stream or a morass, or in any manner falls behind the herd, when they attack and devour him.

It is estimated that the herds of buffalo are at present fifteen millions, and that they are accompanied by one and a half million of wolves.

How the scene sweeps on! it confounds all conception of distance. Those must be a herd of antelopes yonder. How beautiful they are! That herd before us, beyond the river, appear to be horses. They are a splendid herd of wild horses, descended doubtless from horses of Asiatic or European origin, which have run wild from the early Spanish colonists; satisfied with feeding, they are calmly gazing at the setting sun, or lying down amid the luxuriant verdure.

You must be constantly on the alert to notice everything, and especially the villages and scattered encampments of the Aborigines, the athletic sports and dances, the loves and parental affections of the wandering nations, their feats of horsemanship, of archery, and of war. We have around us the range of the powerful bands of the Pawnees.

Observe yonder, far before us, a mounted huntsman is dashing on a herd of buffalos. The sweeping flight of the herd rushes over the hills—they are coming right towards us. He has singled out one from the herd—his bow is already bent—the victim falters behind his fellows, staggers, and falls. The hunter rejoices; his lodge is one of that cluster of brown spots you may notice yonder, a league south of us on the prairie.

He will arrive there an hour hence, laden with abundance. He will bless the moon as she shines on him. He is happy. He possesses all that he has learned to want.

The landscapes now sweeping beneath us are those of the thousand streams of the La Platte—

> Where oft the beaver with mechanic art
> Delays the current of his native brook,
> To form a play-pond for his happy young;
> A little lake in mountain scenes embraced,
> Where seldom e'en the vagrant hunter strolls,
> And Nature glories in her primal bloom.

It would be admirable to see these interesting animals at full work by moonlight. You might devote some night to observe them, as well as the habits of all the carnivorous and night-wandering animals, the dances of the Pawnees, and the spectacle of fire on the prairies.

Look at those otters on the bank yonder; how playfully they slide and tumble into the water! There must be the hut of a trapper, probably deserted since last winter. Those black clumps you notice in the summits of the blasted-topped cottonwood trees by the river, are the nests of the vulture or of the eagle.

The one before us will pass directly beneath our feet, we will examine it attentively; you must, however, avoid the attacks of the old eagle.

What a commanding view of the bend of the river; how tranquilly the noble bird gazes on the evening sky! See! there are two young ones half fledged.

What an air of self-complacency and comfort those vultures have! They have gorged themselves on what seems to be a buffalo's carcase, and are now taking their repose. Their felicity is doubtless complete.

What is that on the prairie? It must be a marmot or prairie dog. Look! there are numbers of them. They are coming out, now it is evening. How they bark! There are thousands and tens of thousands. Their burrows seem to occupy a whole horizon of prairie.

Hitherto we have been so much occupied with the landscape and its groupings, that I have yet scarcely called your attention to the sunset skies before us.

Our position in relation to the sun remaining unaltered, the broad horizon of atmosphere, chequered with clouds of constantly varying density, is silently rolling over us—while the landscape is gliding quietly below.

This transparent curtain, illumined by the lights of the heavens in all their gorgeous, everchanging glory, preserves one continued sunset before us, corresponding to the hour of our departure, and to the actual colourings of the moment on the scenes we are surveying.

The loveliest and most vivid reflections appear in rapid and pauseless succession, and fade away toward the eastern horizon; behind you, more numerous than those changes which the sunset skies of your whole life will present, they form a kaleidoscope of celestial magnificence, and shed the most enchanting lights and shadows over the exuberant wilderness.

I must here beg you especially to recollect the purpose for which we ascended, three hours since, and that your vivid realization of the scene depends on your own attention; all I can do is to point out, occasionally, objects of interest. The landscape is rolling beneath you, you must observe for yourselves.

If you were to follow out this method of observing the picturesque panorama of our comparatively little, yet magnificent planet, in connection with the grand fact of its everyday revolution on its axis, you would suppose yourself often on various parallels, and devote a day to the contemplation of nature. If you start at the equator, you would realize the high temperature, and observe the peculiar animal and vegetable life of the torrid zone; if you take an arctic or antarctic position, you would realize the extreme cold of those desolate regions; you would thus become familiar with all the localities, the natural history and inhabitants, so as in the aggregate to form one entire, continuous, comprehensive outside view of the globe we inhabit, and of its daily rotation. This idea it is the purpose of this chapter to suggest.

It will be expedient, as your perceptions of the face of nature approach to distinctness, that we begin to study and to compare the habits and characteristics of the human race—that we contemplate man, the thought-gifted animal, as he has existed during a long series of ages, and trace the ancestral and inherited characteristics of the nations.

This will more appropriately claim our especial attention, when we come to survey the homes of those nations of antiquity, whose progress in arts and arms has been commemorated by more enduring monuments, indicative of high civilization, and where the early invention of letters has preserved for us some historical memorials of the vicissitudes of empires; but the general influences of climate, of soil, of a mountainous or champaign country, of mines, and of mineral treasures on the human species—the conflicts of more civilized with more barbarous tribes, the progress and retrogression of empire, and the mutability of human achievement, may be worthy of a momentary retrospect before the wide valley of the Mississippi has passed, with its numerous mounds of extinct nations, who have lived and hunted on its far-spread streams.

The following stanzas were written when the author was amid this scenery, and may not be irrelevant. Whatever be their practical merit, they have at least the recommendation of being a "sketch from nature:"—

### THE PRAIRIE.

Twilight curtain'd the far-water'd plains of the west,
The landscape grew dim to the wanderer's eye,
All was still where the prairie-bird guarded his nest.
The sun's path was red o'er the place of his rest,
And the vapours that loom'd on the verge of the sky
Were bright as the hunter's dream'd land of the blest.

The bones of the bison were bleaching around,
The herds had lain down 'mid the wild flowers' bloom,
And heaven's wide concave seem'd vacant of sound,
Save where some lone prowler's fierce howl rent the air;
The breath of the desert was fraught with perfume,
And the brief fly of summer in gladness was there.

I had sealed the steep cliff o'er the eddying wave,
Whence the love-martyr'd maid in her beauty had leapt,
And encamped on a spot where the fair and the brave
In the dust of the desert all silently slept;
Where the Osage had dug for their chieftain a grave,
Where their hazel-eyed matrons in madness had wept.

The still heavens glitter'd with many a star,
The lone dewy desert grew darker and drear,
I shrunk 'neath my robe, for my home was afar,
And my heart's sombre musings were blended with fear:
Kind sleep sealed my eyes, such as wanderers know
When the lonely are blessed with oblivion of woe.

Deep visions stole o'er me with tragic-wrought power,
Like glad sunset groupings of years that have past,
Restoring the magic of many an hour,
Too fleeting to tell, and too lovely to last.
Proud races of chieftains, their loves and their rage,
On the prairie's vast outline burst bright on my eye,
Like the song-storied glories of earth's early age,
Like a vast pictured legend portrayed on the sky.

The season's rich dramas of bloom and of change,
Each rife in its redolent beauty and prime,
Gave shadow and light to the vision's wide range,
And varied the still pauseless fleeting of time:
The winter's hunt scenes o'er the far-drifted snow,
The fawn's happy frolics, 'mid spring's blossoms past,
The flower-fly's flight in the summer-sun's glow,
And autumn's sweet songsters, the lonely and lost—

The hunter's gay smiles on his fond mother's breast,
His nurture, his gambols in life's happy morn,
The spells of his manhood's impassioned behest,
The flash of his eye on his battle-steed borne;
The victor's shrill joy, the still death of the foe,
The feats of the brave, and the right of the strong,
Swell'd my heart with high pulses of joy and of woe—
But no prairie minstrel has told them in song.

Here swept o'er the wild-grass the whirlwinds of war,
Here the vulture for ages has nourished his brood,
On the flesh of the proud and the fearless of yore,
'Till the cliffs of Missouri were died with their blood.
And here, when the autumn-moon tranquillest gleams,
Gave wilder enchantment to beauty's kind glance,
The glad hunter, 'tranced in his heart's dearest dreams,
Seemed to reap in life's fancies the joys of romance.

'Twas morning—I woke on the wild pasture space,
Where the vast prairie spreads in its grandeur alone;
Around me, far peering, the turf-mounds were strown,
Where the mighty had heaped them a burial-place—
The lone lasting record of many a race.

The races of the aboriginal hunters have successively retired from their forest hunting-grounds on the hills and valleys and rivers of the Atlantic, toward the cataract of the Great Spirit, and to the broad plains where the countless streams of the Father of Rivers gather on the mountains of the setting sun. The lands of Metamora, of Red Jacket, of Pushmataha, belong to the pale faces. Keokuck, "the watchful fox;" Mahaska, "the white cloud;" Tecumseh, "the open door," have fallen. Kiontwogky, "the corn-planter;" Anpantango, "the big elk;" Terrekilaaher, "the unequalled;" O-poth-ye-ho-lo, and Sequoya, and Osceola, have yielded to the insatiable white men.

Let us contemplate the lapse of time, the swift course of the seasons, of human events, of generations, in connection with the scenes around us; the certain return of the buds and birds of spring; the full verdure of summer; the party-coloured foliage of autumn; the white snow-drifts of winter, as they have alternated for countless and unrecorded ages upon Central North America. Let us call up from oblivion the long line of generations of men, as they have succeeded each other in certain accordance with the course of ages, the frolic and prattle of the infant savage, his youthful sports, the deep passions and enduring energy of manhood, the thoughtfulness of experience, the repose of the grave, as they have passed over long series of generations; the utmost strength and prowess, the most enchanting beauty, deep affections, filial, conjugal, parental, insatiable ambition, indomitable courage, as they have flourished beneath the vast pavilion of the primal forests; or have exulted in the glad light of heaven, like the wild flower in the boundless breeze of the prairie, and have passed away—nothing, save a few dim and unsatisfactory traditions remaining.

If you will thus trace back the events of the last three centuries, you will restore to the American continents their original scenery before the voyages of Columbus; and may study the primeval differences, and entire comparative natural history, which the Creator has impressed on the whole face of the two hemispheres. Their races of men, distinct in condition, civilization, characteristics; separated by the yet unnavigated Atlantic—Mexico unconquered—Africa unenslaved.

The wandering tribes of red men, whose home is beneath us, we are accustomed to call savage and barbarous; it is, however, true, that in some of the nobler traits of human nature—bravery and endurance, constancy and courage, and rational ideas of divinity—they may be asserted to have equalled, or excelled the original nations of the Eastern continent.

The native American "sees God in clouds, and hears him in the wind." He worships the Great Spirit, and communes with him in his loneliest moments; he has benevolently attributed to the beasts of the forest a sort of demi-brotherhood, and believes that his translation after death to a region of tranquil exuberance and unearthly felicity, will be shared by the rudest animals of the chase, and that especially "his faithful dog will bear him company." But the native American has not degraded himself, by deifying the brute; and while the older nations of the East worshipped all sorts of idols, the "likeness of every thing that creepeth under heaven," he has exempted his crude and indistinct perceptions of Deity from such gross and disgusting delusions.

To the accidental discovery of the metals and their uses, with the consequent arts, is probably to be attributed the more rapid progress in civilization which the eastern continent has achieved; the evidences of combined effort, the monuments which they have left to posterity, though built of more enduring materials—granite, porphyry, and marble—appear to have been for very analogous objects, security from inundation, and burial-places—(for the feeling which prompts to some feeble effort at giving reminiscence to the spot of his mortal resting-place, seems to be universal with the entire race of man, wherever dwelling); along the valleys and on the prominent bluffs of the tributaries of the Mississippi, the rude stone and earth-heaped mounds of sepulture are very frequent, and are chiefly attributed to ancient and extinct races of the aborigines.

The unwritten languages of the natives of America have assured no records of their early history, other than a few faint traditions. The structure of these languages possesses the same evidence of progressive combinations of the simplest ideas, which are the natural origin of primitive language; and such wrecks of them as will be preserved, will afford constant interest to future philologists, when, as appears to be the destiny of the future at the end of one or two centuries, the ploughshare shall have obliterated the only frail memorials which now indicate the existence of the ancient nations of the American continent.

But I have too long diverted your attention from the passing scene.

Those remotest cloud-like outlines you may now begin to distinguish in the horizon, are the snow-capped summits of the Rocky Mountains, over which the splendid light of the evening falls with delightful effect on the long intervening leagues of forest, intersected by ravines and washed by cascades.

The myriad plants of unknown beauty—the treasures of the mountain strata—the amazing developments of the geological eras—the countless tenants which inhabit the plains, the forests, and the mountains, which sport in the brooks and

flutter over the flowers, are inconceivable. But you must not stop to examine them with the interest of a naturalist; you cannot expect to embrace everything in a day. You must observe, therefore, comprehensively and with promptness. The grand study of our present survey is *Generalization.*

The higher mountains are rapidly approaching—we must ascend.

We have now below us the westernmost fountains of the Missouri, and the summits of the Rocky Mountains. We have filled with living groupings, with sketches of actual life, the whole scenery; and have attributed the thousands of streamlets to their respective rivers, and observed the forests and fields, the plains, and ravines, and mountains, each rife with all its appropriate inhabitants. We chose, you know, for our excursion, the season of harvest and the hour of sunset, and have witnessed a sunset landscape of a thousand leagues, with all the actual imagery as existing at the passing moment.

The summits passing below us are the "cloud-capped hills," beyond which the wandering tribes of Missouri picture the land of the blest, the "humbler heaven" of their future hopes—

> "Lo, the poor Indian, whose untutored mind
> Sees God in clouds, or hears him in the wind;
> His soul proud science never taught to stray,
> Far as the solar walk or milky way,
> Yet simple nature to his hope has given,
> Beyond the cloud-capp'd hill, a humbler heaven."

We are on the fortieth degree of north latitude. The vast ranges of mountains beneath us merit especial observation; they extend northwardly to the unexplored Arctic; let your mind's eye for a moment trace them thither. And now, turn your eye southward, and trace them by the mountains of Mexico and of Darien. Observe where their eternal snows glisten in long perspective across the torrid zone, till Chimborazo rises in the lengthening line, and further still, to the southern extremity of the western continents.

The mountains are passed. Beyond them the vast horizon bursts upon us. The streamlets now beneath us are the southernmost tributaries of the Columbia.

It was here, a few short years since, that the intrepid companions of Capt. Merriwether Lewis hailed the rivers flowing to the Western Ocean, and looked down upon the far-spread home of savage nations, untrodden by the footsteps of an European.

> "His was the peril, glory, pride,
> First of his country to explore
> Whence vast Missouri's currents glide,
> Where white man never trod before.
>
> These roaring cataracts he scaled,
> These mountains of eternal snow;
> Here his brave band the rivers hailed
> That westward to the ocean flow.
>
> Subdued by boldness, and amazed
> At daring deeds unknown before,
> The hordes of Indian warriors gazed,
> And loved them for the hearts they bore."

The mountain wilderness of enormous fir-trees, which shades the southernmost tributaries of the Columbia, is sweeping silently in the evening sunlight beneath us. Do you notice how different the forest appears? It is composed of entirely different species from those of the valleys of the Susquehanna and Mississippi; the oaks, and hiccories, and walnuts, the buttonwood, the liriodendron, and the maples, have disappeared. You may notice several species of birch and ash, and one species of dogwood; but the predominating genera are the resinous trees, and the most majestic species of the firs are widely multiplied in these regions.

Let us occasionally descend beneath the shade, and observe in their native haunts the habits of the peculiar wild animals of these central solitudes.

Primeval stillness reigns, interrupted only by the breeze gently swelling in the old forest, or the leap of some fountain cataract, playfully commencing its pilgrimage to the distant ocean.

Hark, that rustling! Yonder he is, a noble elk, browsing. Look, look at that panther, there in the tree. Ah! he has pounced down on the elk.

The stricken victim dashes through the forest with the energy of despair; he throws back his branching antlers, the panther retains his hold, his carniverous teeth have already opened the streams of life. The elk has fallen.

Here the brown wolf prowls at midnight, glutting his thirst for blood on the sheep of the mountains. Here, too, the fierce grisly bear exacts his tribute of blood: within his rude gripe the timid deer bleats, and the proud horse struggles in vain.

Yonder, beyond the ravine before us, on the verge of that precipitous, inaccessible bluff, a ring-tailed eagle, the fiercest of the American falcons, is alighting on his nest. The party-coloured plumes of this bird are highly valued, and form, as you may recollect, the crests of the chieftains of the plains of Missouri. The red men on both sides of the mountains have an idea, that the qualities of noble animals are imparted to the wearer of their spoils; and their barbarian warriors, like those of old Greece, pride themselves in wearing the skins of the fiercest animals.

The country before us is now becoming more level, and intersected by broad and fertile glades, traversed by the larger tributaries of the Columbia, tumbling in gentle rapids, or flowing with glassy stillness, amid sweet wooded islands.

What is that Indian doing? He is fishing. Look! he has just caught a large fish. It is a salmon. What very various costumes the Indians have! they appear to be fashioned in countless modes, from every skin and every feather of the forest.

The lodges of the red men are more numerous. Yonder is the largest village we have passed this side the Rocky Mountains. We seem to be approaching prairies again; the vast plains of Columbia are before us, green in the fullest verdure, and teeming with thousands of herds of buffalos, of antelopes, and of horses; 'tis the range of the Shoshone Indians. Will you notice this tribe especially? they are numerous, powerful, and unsurpassed in horsemanship, in classic figures and indomitable courage, by those cavaliers of ancient Numidia, who followed, twenty centuries since, the hero of Carthage to the gates of Rome.

The Tartar Asiatic origin of the American tribes has been contended for by able students of nature, and has certainly considerable corroboration in the analogy of their organization.

What are those dark groups yonder, on the distant prairie? They are bands of horsemen. Hark! 'tis the war-whoop! Bands of archers, mounted on the wild steeds of the desert, are charging in irregular combat. 'Tis a fierce and deadly battle. The storm of horrid war sweeps on, and we have again the silent and boundless prairie.

Do you notice that cloud-like line in the west? 'Tis another range of mountains. The grassy horizon of the plain, with its herds of elk and antelope, has passed, and you again trace the fountains of the Columbia, and its far-winding tributaries, amid a thousand landscapes of undulating and mountainous forest.

Do you hear the roaring? We are approaching the great cataract of the Columbia. What a sublime landscape! Observe it attentively. The fall must be more than double that of Niagara. Look at those bald eagles, they are always partial to the vicinity of cataracts.

The scene rolls on. Fir-trees, a hundred yards in height, cover the hills with deep verdure; vast amphitheatres of unknown foliage, occasionally diversified by grassy glades, spread in luxuriant beauty over the valleys: the waters of the Columbia, for hundreds of miles, are alternately struggling beneath us for long reaches in narrow ravines, where the streams empty themselves in cascades from the hills, tumbling in foaming rapids over its rock-obstructed channels, or flowing with gentle current, where the hills recede to the horizon, and give place to wide and fertile intervals.

Those animals you now occasionally notice amid the rocks of the river are the sea-otters, whose rich furs form a valua-

ble object of commerce, and purchase for the natives the utensils and the trinkets of the white men.

The otters are appearing in great numbers. We are approaching the last great rapids, at the foot of which the descending waters meet the tides of the Pacific.

The wild scenery of the rapids is past. We have now beneath us the widening delta of the Columbia. Clouds of ephemera are commencing their flight from the tranquil waters; the groups of red men are enjoying their evening meal, and pursuing their various employments on the shores, or paddling their bark canoes to songs of harmonious cadence, amid rich meadows and wooded islands, fertile by the reflux of the Pacific Ocean. The geese, swans, gulls, and other water-fowl, are squalling on the shores and sandbanks; the breakers are roaring at the foot of the distant bluffs.

We will pause for a moment, where the mountain before us obtrudes its lofty and precipitous height into the sea. Immediately in front is the ocean, which breaks far below at our feet, and on either hand, as far as the eye can reach, against the bluffs and irregular piles of rock which diversify the shore; on the right is the sheltered estuary of the Columbia, widening into bays and islands, studded on both sides with the little reed-thatched villages of the red men. Behind us is a rich scene of forest and prairie; before us the immensity of ocean, empurpled by the setting sun. Do you see there a ship, I presume a fur trader, at anchor in the offing? On your right another sail is visible in the distance.

The receding shores of Western America are now fast fading behind us; for six successive hours, more than a fourth of the earth's circumference, two thousand leagues of billowy boundlessness will sweep beneath us. Let us embrace the occasion to observe such of the atmospheric phenomena of the ocean as the range affords.

Before us, the incessant and ever-varying glory of the sunset sky is mingling with the horizon of the ocean. A summer shower is approaching; let us ascend above the clouds, and hear the thunder rolling in the sunlit masses below us, " o'er the wide waters of the dark blue sea."

In this vast tract of ocean, rolling in one broad expanse from amid the beautiful palm-tree islands of the sunny tropics, to where on either side it is eternally dashing on the ice-cliffs of the Arctic and Antarctic, what an amazing variety of fishes and shell-fishes have their home!

The following stanzas are an attempt to illustrate the residents of the bed of the ocean:—

### THE SONG OF THE SEA SHELLS.

Where the water-plants bloom in the fathomless ocean,
O'er regions more wide than the verdure of earth,
Deep down 'neath the broad waves' far-heaving commotion,
Kind Nature allotted the scenes of our birth.

Where'er the blue billow in boundlessness rolls,
Or the moon-lifted tide-swell is pauselessly piling,
From the icebergs that gleam on the star-lighted poles,
To the glad Isles of Atlas, perennially smiling,
'Neath the path of the sun; where the coral-rock grows,
And the last weary surge of the trade-winds repose;
There our tribes are all dwelling in gladness and pride,
'Mid the pastures of ocean, untraversed and wide,
In numbers computeless, and colours that vie
With the blossoms of earth, and the lights of the sky.

Where the frost-night of winter encrystals the wave,
Where the blazing sun sinks 'mid the flush'd ocean's smiles,
Where the grampus or dolphin have found them a grave
'Neath the poles' cloudy cliffs, or the palm-shaded isles;
Where the pearls of the orient in loveliness sleep,
And earth's richest treasures and men's bleaching bones
Are scattered abroad on the plains of the deep,
Neglected, unprized as the beach-weather'd stones,
Where the brass-sculptured galleys the Argonauts bore,
Still curve their bold prows half-interr'd in the sand;
The fleets which have sunk 'neath Charybdis' roar,
And the time-wasted wreck-ribs of every shore,
Which ocean's old rovers have left on the strand;
There our kindred are sporting in joy and in pride,
O'er the pastures of ocean, so fertile and wide,
In numbers computeless, and colours that vie
With the gems of the earth, and the lights of the sky.

Where the canvas of commerce has courted the breeze,
And gallant ships, gay as the clouds of the hour,
Have swept o'er the mountain-wave waste of the seas,
While traffic-built cities grew peerless in power—
Where the fleets of dead empires have crowded the wave,
And navies have reel'd to the cannon's deep roar,
To swell in proud annals the fame of the brave,
On the archives of ages, whose glories are o'er—
Where the nautilus lifts his light sail to the breeze,
Where the mariner sings to the sky-circled wave,
By the rock-sheltered inlets and isles of the seas,
Where the far-fabled syrens enchanted the brave—
There our tribes are all dwelling in gladness and pride,
'Mid the pastures of ocean, so fertile and wide,
In numbers computeless, and colours that vie
With the blossoms of earth, and the lights of the sky.

Where'er the wide azure its barriers laves,
Where the surf of the summer breeze playfully roars,
Or the far-heaving surge of the storm-fretted waves
Rifts up ocean's relics on earth's furthest shores—
There, while glad sunlight fades o'er the ocean's white foam,
And the cool breeze of evening blows fresh on the strand,
The blithe sea-boy, sadd'ning in thought of his home,
Is gath'ring gay shells from the billowy sand,
While he grieves the hard fate which has doom'd him to roam,
And visits, in visions, his love-lighted land—

He shall bear them away from the scenes of our birth,
And bright eyes shall value his far-gather'd shells,
They shall haply be group'd o'er some bright glowing hearth,
Where affection has woven her home-nurtur'd spells,
Where kindness still welcomes the wand'rer of earth,
And his heart's fondest day-dream of happiness dwells.

Look at those flying-fishes! a shark is after them. They fly out of the water to get out of his way, but they cannot fly very far, and the shark will probably make a supper of some of them.

Look yonder, it must be a whale spouting. See, there are others. What is that on the horizon? It is a sail, a ship. Look, there are more whales, the boats are after one of them. See, they are going to strike a harpoon into him. Down he dives. He has come up close by us. He spouts blood. They will get him, and bring his oil home.

These hardy navigators are chiefly natives of the United States. Sailing from a barren sand-shoal island of ocean, and a rocky inlet of the Western Atlantic, their canvas whitens the oceans of both hemispheres, and pursues the various species of whales in their respective haunts, from the icebergs of Greenland to the Straits of Behring, and amid the countless islands of the Southern Ocean.

Let us assume a high elevation, and while the gently rolling billows of the broad Pacific are rapidly fleeting in the evening light below us, ere we approach the shores of Asia, I wish again to command your attention to our motto, " generalization," and to call your attention to the splendid and glorious reflection of the sunlit skies, which are at this moment shedding such magnificent light and shadows on the empurpled ocean.

You will also notice the China trading ships, and find, among the navigators of the Pacific, your own townsmen and friends, who, though they will consider ours a visit unrivalled in naval annals, will be not the less gratified to see any one so lately from their far-distant home.

Do you notice that dark line which bases the sunset glory of the western horizon? It must be land! Is it possible that two thousand leagues of ocean scenery have swept under us so soon? 'Tis land, certainly. It must be the Japan Islands. It is the shore of Cape Nambu, in the Isle of Niphon.

The Isle of Niphon, its shores enlivened by boats of peculiar construction, with latteen sails, veering to the breezes, and the town of Achita, and beyond the inland scenery and landscapes robed in the characteristic vegetation of Asia, and bright in the sunset glory of the summer solstice, sweeps for one hundred miles beneath us.

We have again an ocean horizon. It is the sea of Japan for two hundred leagues. The countless vessels of various construction you observe in these seas, are the coasting commerce of China. We are approaching the shores of tho Celestial Empire, the most populous of nations.

Do you notice that black cloud on your right? It must be a typhoon or hurricane, of which you have read as occurring on this coast. Where shall we meet it?

Above the cloud, or down near the ocean? See how the boats and vessels are furling and clewing up sail. It will be on them in a moment. Look how dark it is under the cloud. Here it comes. That boat is capsized. Look at that ship,

how she heels to it. Do not tell me to look, I cannot see anything. However, we'll soon be through it. What a dreadful squall! Let us rise above the cloud, and look down on it. How awfully it thunders! It is leaving us. It passes on like a whirlwind.

'Tis past. How bright the evening sun shines on the relics of the storm, and the sad destruction it has caused! Thus days and years progress. Time pauses not over the fate of individuals.

The land you may now begin to distinguish in the horizon, is the Isthmus of Corea. The peninsula sweeps beneath us in broad perspective, the town of Tchang-chow, and two hundred miles of landscapes, bringing us to Kirin, the most southern province of Tartary.

The ocean scene, sweeping in the distance on our southern horizon, is the head of the Yellow Sea, or Whang-Hai, in the language of the natives: the breakers are roaring on the coast of Tartary; below us is the hilly and woody promontory, from which Pekin obtains much of its timber; before us is sunset on the Gulf of Leaotong.

As the continent of Asia approaches, we will for a moment ascend to a great elevation, in order to view its widest topographical characteristics.

We are on the fortieth parallel. The coast of China, extending south through nearly twenty degrees of latitude, presents a vast breadth, populous with coasting vessels, and green in summer verdure.

China is in extent one-third larger than the United States east of the Mississippi, and the Chinese Empire, extending through the extreme breadth of Tartary, surpasses in extent the entire territories of our country. It comprises one-fourth of the soil of the temperate zones, and some of the finest rivers and largest cities of the earth, and contains three hundred and fifty millions of people, who have lived for thousands of years under stable political institutions.

But little, comparatively, is known of this immense and swarming hive, as the internal regulations of the empire, till lately, prohibited intercourse with foreigners, except under strict surveillance, and for purposes of trade, at a single port, Canton, which is a city of a million of inhabitants, eighty-four thousand dwelling in boats on the river Hoogly.

Its inhabitants call it the Celestial Empire, and boast for its archives unrivalled antiquity, not yielding in national self-importance to the smaller but more ambitious and quarrelsome nations, who have figured in the eventful history of the European side of the continent.

Almost below us, stretching with its windings to the west, is the Great Wall of China, which may be said to separate two people. On the right, extending far into the northern parallels, you will notice vast tracts of pasturage, and the herds and flocks of the Manchow Tartars, who are almost exclusively a pastoral people; while on the south extend tracts of landscape, imbedded with the garden-cultured fields of the Chinese, who are, as exclusively, tillers of the earth.

You may notice that the climate, and some of the cultivated productions of Eastern Asia, are not in all respects unlike those of similar latitudes in our own United States.

The famous wild plant ginseng, to which the Chinese attribute wonderful properties, and which is gathered as an exclusive monopoly for the emperor, grows in the province of Kirin, in Manchow Tartary, in similar latitudes and mountainous situations to those in which it is found in the interior of Pennsylvania, and from whence it is sent round the half circuit of the globe to China, as an article of commerce.

In the United States, the grasses are indigenous on the fortieth parallel, and north of it. These are the latitudes where the horse, the ox, and the sheep flourish. Grass is the staple of New England. A few degrees south of the fortieth, we verge upon the planting states, and grass begins to be less generally and profitably cultivated. Such is precisely the case on the Asiatic side of the planet.

The horses and cattle of the more southern parallels tend to deteriorate from the heat of the climate. Labour is there performed by the mule and the ass. "In the whole of central and southern China," says Mr. Davis, late British Chief Superintendent in that country, "there is no good land for pasturage. The cattle and horses are, accordingly, poor, and of stunted appearance; in no country in the world are fewer cattle used for the purposes of draught or burden. No people consume so little meat, and none live so much on fish and vegetable food. Towards Pekin, the case is somewhat altered." This is obviously because you there find the proper latitudes of the horse, the ox, and of their appropriate food, the grasses.

Oats, in all parts of the earth the most northern of grains, is grown in Tartary, as well as in Siberia, Scotland, and the Canadas.

Wheat is also grown in its proper latitudes in Eastern Asia. In China, millet seems to substitute food to those latitudes in which Indian corn is a staple on the American continent. Those more southern parallels, which in our own country are respectively suitable to the culture of tobacco, rice, cotton, and sugar-cane, are in China devoted to tobacco, the castor-oil plant, the mulberry and silk culture, extensively to the tea plant, tea being almost universally drank in China, and largely to rice, which forms the chief food of Southern Asia—and also largely to cotton and sugar.

To the north, the apple and the pear tree flourish, the grape grows in the central provinces, towards the south the yellow and the crimson orange. On the uncultured portions of the hills grow the camphor-tree and the downy myrtle. The shrub you may notice on the hills, now so fragrant and white with a prefusion of blossoms, is the camelia oleifera, the seed of which furnishes the favourite vegetable oil of the Chinese.

The coast of China in this latitude is flat and alluvial, and intersected by large rivers and canals, which traverse the extensive valleys and level lands where the rivers are banked out by dykes. Over large districts, careful irrigation forms a part of the system of culture, by which they contrive to render the soil more productive than the best-cultured acres of Europe, and much of the land is subject, like those of Holland, Egypt, and Louisiana, to destructive inundations, when the floods of the rivers overflow the embankments.

The town of Yong-Ping passes somewhat south of us. Some leagues to the south you may now observe Teen-tsin, a city of 700,000 inhabitants; it is situated on the Peiho river, at the point of intersection of the canal, the capital, and the ocean. It is the seaport of the capital. It must be a place of much business. At a distance, it has the appearance of a large European seaport. Those white masses you see piled in the neighbourhood are of salt, which is largely manufactured on the marshy borders of the sea adjacent, and whence it is distributed for the consumption of the capital and the empire.

Below us is gliding one of the most fertile and carefully-tilled regions of earth. Let us descend. Do you notice those large flowers growing in the shallow lakes, and by the sides of the canal? Pick one. They are very fragrant. Do you not know it? You might have seen them growing in some of the ditches a mile or two south of Philadelphia, where they have been naturalized. It is the nelumbium or lotus, the seed or nuts of which they use for food.

In the more southern provinces of China, they raise two crops of rice during the spring and autumn, and a crop of petsae, similar to our cabbage, and other vegetables during the winter.

The country here is a level alluvial plain, with but few trees. You may notice the weeping-willow and the elm. What is that fine tree yonder? It seems to be a species of ash.

Look around; what a splendid scene of cultivation! The country looks like a continuous garden, scattered with the huts of the peasants. Scarcely any roads, fences, or hedges, are to be seen. As there are few cattle and wheel-carriages in the country, the fields are separated by narrow footpaths, and by ditches and banks.

The labour, in other countries done by horses, is here mostly done by men, and you notice also many women at work in the fields. That is a venerable-looking old peasant. I should like to converse with him. These people are the countrymen of the learned and philanthropic Confucius.

That is a beautiful garden. What large, splendid flowers are those? They must be pionies; they are here indigenous. If you were three months later in the year, you would see forty varieties of China asters. China, bright with its rolling curtain of sunset skies, the present fragrance of summer, and the evening songs of summer birds, is below you. You must observe with attention, or, amid the many groups of new objects, much will escape you unnoticed.

Its hundreds of millions of acres, minutely divided, and under the most careful culture, its indigenous vegetation, its men and women peasants, its villages, its artisans, the establishment of its peculiar manufactures, which, although in some respects inferior to those of Europe, are in others unsurpassed in the world. The Chinese were the first inventors of gunpowder, of the magnetic compass, and the art of printing, all of which have been improved upon in Europe.

What is that in the horizon? Hollo, boy, what is that yonder? 'Tis Pekin. Ah, we are approaching Pekin, the largest city in the world. Let us rise somewhat, we can here see only the wall. It will pass directly under us. It contains two millions of people. You will have a fine opportunity of seeing the characters, costumes, and institutions of the citizens.

The southern portion, on the left, is the Chinese part of the city, which is the most populous and elegant, though the northern portion, or Tartar city, comprises the palace of the emperor.

Observe the wall. It is of blue brick, castellated and flanked with bastions. It is thirty feet high, and twelve miles in circumference.

Do you observe the roofs of its public buildings, covered with yellow-varnished tiles, which, fluted in gentle curves, and variously embellished, glitter like gold in the setting sun?

Immense magazines of rice, and the Altar of the Sun, characterise the north-eastern angle of the city. That building on the south of the rice magazines is the Astronomical Observatory of Kinsing, or the Planet Venus. That high building you notice on the north is the Choong-Low, or Bell Tower, near to which is the office of the General of the Nine Gates, or Head of the Police. South of this, the enclosure you notice, occupying nearly the centre of the city, is the Imperial Wall, or Citadel. It is an area of about two square miles, and contains the emperor's palace, with its splendid artificial hills, lakes, parks, pleasure-grounds, and gardens.

Do you observe the broad regular streets? What throngs of people crowd the principal thoroughfares! The front rooms on the principal streets are splendid shops. What is that procession all in white costume? 'Tis a funeral of a high officer or mandarin. What is that they have in those baskets? 'Tis ice, certainly; they use ice and coal here as well as on our side. There is another procession; you notice that the costumes are all gay colours, and that no one is in white. This is a bridal. These people are very good-looking, and seem in fine spirits. They are natives of a favoured latitude. What a lovely summer evening! What a vast hive! The people seem all in the streets. The citadel or central city is below. Observe the military costumes of the guards. They are chiefly Tartars, as the emperor is descended from the Tartar conquerors of China.

Before us is the palace, rich in barbaric splendour. Yonder, can that be the emperor walking in his garden? It is his Celestial Majesty himself. We will have a look at him. He seems to be rather disquieted. The English "barbarians" have justly provoked him by sending fleets of war-ships and steamers to sustain the opium smugglers.

Let us elevate ourselves, and look down on the whole area of the city. The plain on which Pekin stands is an immense alluvial flat. Towards the west, you have again scenes of culture—the country becomes more hilly.

From the mountains now approaching us, they obtain great quantities of coal for the use of the capital. The mountain sides are fragrant with the white blossoms of the camelia, and numerous flowers blooming in the genial air of the summer solstice.

We have now one hundred leagues of Chinese landscapes, well-cultured plantations, and populous villages of the Celestial Empire, bringing us to the Great Wall, the north-western boundary of China. The wall passes under us, and Chinese Tartary, or Mongolia, is before us. We pass the sources of the Hoang-Ho, and have now for twelve hundred miles the vast deserts of Shamo and of Sultus, where the boundless plains and steppes, the grazing range of the ox of Asia, alternate with tracts of sand, which drink up the rivers flowing to the north from the Altai or Mosart, and on the south from the Kuenlun or Mustag Mountains, which separate Tartary from Thibet.

Vast herds of oxen, grazing upon the immense steppes, herds of antelopes, hares and sand partridges, and the roving pastoral equestrian tribes of the wandering Tartars, diversify the sunset horizon.

We have now had, for twelve hours, the sunset scenery of one half circuit of the revolving globe. One hundred and eighty degrees of longitude from Philadelphia have swept under us. It ought to be borne in mind, that the earth's circumference on the parallel of the equator, is more than twenty-five thousand miles; on the twentieth degree of north or south latitude, it is over twenty-three thousand five hundred miles; on the fortieth, nineteen thousand two hundred; on the sixtieth, twelve thousand six hundred; on the eightieth, four thousand three hundred miles, converging to a point at the poles, or the ninetieth degree of latitude.

The pastoral villages of Kintan, Toula-Kapta, and Chachow, belonging to the various families of the Mongols, the Eluths, the Kalkas, the Sharras, and the Chosotes, sweep under us.

Beyond, on the left, ten degrees southward, Thibet extends to the base of the immense mountain range of the Himalaya, the northern boundary of Hindostan. You may observe, for a thousand miles, the continuous groups of summits deeply indented in the heavens; where the far-wafted exhalations of the ocean are condensed in immense glaciers, from whence tumble, in torrent-cleft gorges, the cataracts of the Berhampooter, the Ganges, and the Indus, the noblest rivers of Hindostan. In these mountain ravines you may trace the records of those wondrous geological revolutions which have chronicled the duration of the planet.

Beneath us are the table-lands of Thibet, before us the mountains of Betur-Tag; beyond, Bucharia and Turkistan, provinces of Tartary, sweep for a thousand miles of landscapes, deserts and cultured fields, the home of the robber, and the cottage of the herdsman. On the south are fleeting the flower-gardens of Persia, beautiful with rosebuds and nightingales and love-dreaming maidens, and the spice groves of Araby the blest.

On the north is the range of the wandering Tartars, the Cossacks of the Don, the Volga, and the Dneiper, the provincial empire of the Russian autocrat.

The broad, smooth horizon, where the sunset's glorious variations are now so enchanting, is the Caspian Sea. Its shores are already approaching, and we have again a horizon boundless as the ocean—

"The sea, the sea, the open sea."

The boundless billows are again on every side around us. The various construction, materials, and modes of navigating vessels on the oceans of the earth, are subjects worthy of your notice, from their utility and picturesque interest.

You can now recognize the western shores of the Caspian. Before us is Georgia and the Circassian mountains, the birthplace of the noblest variety of the human species. You will, perhaps, hereafter be able to satisfy yourself on the much discussed question, how far the varieties of men are a result of climate, local advantages, and civilization; or whether, and to what extent, original differences of organization have caused the very striking diversities which exist at present.

Before us are now approaching the mountains of Caucasus; their valleys and elevated plains, the nursery of a race the most fortunate in intellectual endowments, and most beautiful in physical contour, which has subjected and colonized the whole western hemisphere, less, probably, by the warlike superiority of its characteristics, than by its superior intel-

lectual and moral qualities. The mountain you now observe is Mount Ararat, so celebrated in the sacred history of the patriarchs as the spot where the ark rested in the midst of the waters of the deluge. Around us are the seats of the old empires of Asia, the earliest home of civilization.

Below us is the vale of Mount Shinar; the range of the rescued antediluvian shepherds. The rivulets beneath us are the tributaries of the Euphrates aud the Tigris; the successive scenes of the pride and greatness of the Assyrian, the Babylonian, and the Persian empires; now only recognizable in the mouldering and moss-grown ruins of their deserted cities, where the bittern dwells in solitude, in fulfilment of the predictions of the prophets.

The present cultivators you will notice frequently kneeling in their fields: it is the hour of their evening worship: they are the disciples of Alla and of Omar, devotees to the enthusiasm of the prophet Mahomet, subjects of the far-spread, but feeble and declining empire of the Ottoman Porte. Before us are the landscapes of Turkey, fleeting in the sunset light, presenting in vivid reality the actual condition of her people and her iustitutions; the most impressive results of her history and her characteristics.

Before us, on the right, is Constantinople. It is sunset on the sea of Marmora; the old groves, the islands of surpassing beauty, picturesque villages at the water's edge, convents and mosques and remnants of Egyptian, Greek, and Roman architecture, and ruins of its various dynasties. In the distance, Mount Olympus presents its snowy peaks and verdant acclivities, sloping to the sea.

On our southern perspective are gliding the landscapes of Syria and Palestine, scattered with dilapidated cities of other ages: Antioch, and Balbec, and Palmyra, Damascus and Jericho, Jaffa and Jerusalem, celebrated by the history of the apostles of Jesus, and a thousand sacred recollections. Beyond these the spice groves of Arabia the blest; the broad wave of the Mediterranean, encircling the isle of Cyprus; and its southern shores, Egypt, the valley of the Nile, with its cities of temples and pyramids, and obelisks and catacombs; Alexandria, Cairo, Dendera, and Thebes, and the Lybiau desert and the oasis; and still further, where the perspective extends toward the tropic, the mountains of Atlas, their valleys green with groves of palms and acacias, and their declivities gleaming with the glacier cataracts of the Nile.

Over the whole scene the tranquil light of the evening is falling. The mouldering relics, and antiquities, and monuments of past ages of Egypt's celebrated eras, the present various occupations of her less ambitious cotemporary inhabitants, are all before you. I will not disturb your own contemplation of such scenery by any attempts to detail the particular histories of the remarkable monuments, or to decipher with Champolion the inscriptions of antiquity. The whole area of the ancient nations, during the entire lapse of time from the founders of the oldest temples to the present hour, with its patient explorers and careful decipherers of their dubious hieroglyphic inscriptions, must be assiduously studied to acquire in detail the accumulated historical recollections of the race of the Pharaohs. In the midst of this vast landscape you may observe where—

> "The white walls of Akka rise fair from the sea,
> And fertile and lovely thy plains, Galilee;
> Milk and honey are there, and the rose blossoms smile,
> But the wild Arab lurks in the desert defile,
> Where the green Mount of Olives looks far o'er the plain—
> O when shall time waken its glories again!"

In our survey of the American continent, I called your attention to the grandeur and the details of the summer landscape, vivid in all the mature luxuriance and brilliant variety of vegetation and animal existence; in short, to the actually existing cotemporaneous natural history of the earth, in its most stupendous and most minute realities: but, in realizing the history of the human auimal on the theatre of the great empires of antiquity, we must necessarily introduce the idea of progressive or successive periods of time—and contemplate the lineage, character, and achievements of nations, and of successive generations of men, as they have actually appeared and wrought, during their little hour, the humblest labours, or the proudest pageants of the human race.

[As it is an interesting reflection to consider the existing intellectual advancement and moral condition of each individual as an aggregate, accumulated result of the impressions and influences and experience of his whole life—so that, from his early infancy, every one of his waking hours, as well or ill spent, adds its impress to the structure of his mind, and may modify for good or evil his future character and destinies: so it is interesting to study the causes of the transmitted character which events and master-spirits have imparted to races of men, and which constitute the distinctive peculiarities of communities and of nations. The first illustrates the importance of original organization, of good instruction, and of self-discipliue to the individual, as capable of rendering a man every hour progressively a more intelligent and a more perfect being: the second contemplates the importance of the good or bad qualities of the humblest individuals, as influencing the race in general, and as contributing in some degree to the aggregate character and happiness of nations, and even to the entire progressive condition of *civilized man.*] We must no longer *reason* from incomplete premises, but enable ourselves to embrace in our reflections, and to make available to correct and comprehensive judgment on all questions, and on every subject, the whole area of facts, physical, intellectual, and moral, which the whole world presents.

Dr. Johnson somewhere says, that, in proportion as we are able to abstract ourselves from the present, and to fix our attention on the past, the distant and the future, we elevate our intellectual and moral nature. I must ask you to do more than this: amid our vivid panoramic survey, to extend your intellectual horizon until it may embrace the present and the distant, the past and the future, with all their proper relations to each other. We may thus approximate, as far as the feeble, finite nature of the human intellect will allow us, to our idea of the omnipresence and omniscience of the Supreme Eternal Creator of all things.

Such a range of thought would redeem us from local shortsighted estimates—from partial, prejudiced, self-conceited conclusions—from most of the national antipathies, the personal piques, the political feuds, and sectarian bickerings, which characterise the intercourse and affairs of meu, and teach us to cherish broad cosmopolitan views, which, recognizing all the fraternities, and all the contrasts, of the human family, would embrace, with wise philanthropy, the welfare of mankind.

In attempting to realize the whole facts of man's nature, as he actually exists at this moment, in all countries and climates, his institutions, his feelings, his occupations, his entire condition, let us contemplate the distinctive families of men wherever dwelling—not only with a vivid and correct knowledge of their present country and their present character, but with all their transmitted, accumulated, concentrated destinies in past ages, as illumined by the lights of history. Let us trace the nations in their origin, and seek, in the rude and early ages, those individual and generic elements which have given peculiar character to the various races of men.

Let us watch the empire-founding animal, building his first rude cities on the course of some mighty river, as we would watch the mechanic beaver of the mountain stream; let us carefully study the history and emigrations of the conqueror and colonizer of the universe.

Let us, for instance, study the biography of the father of the Hebrews, the founder of a race; let us observe the patriarch Abraham, amid the scenery of his childhood; let the years roll on while we steadily contemplate his youth, his adolescence, his maturity, his old age. Let us follow the changes of his long life with pictorial vividness, till age wastes his athletic form, and he is borne by his children to the sepulchre of his kindred.

Let us carefully follow the biography of his successors in all the varieties of character aud of destiny, which, in the aggregate, constitute the general history of the race; let us contemplate at our leisure, with dramatic truth and power, and with fraternal and philosophic sympathy, the prominent

individuals, and the prominent eras of the Hebrew nation, in their proper succession, as parts of the great continuous procession of human destiny; in which the prattling infancy, the adolescence, the years of physical and mental vigour, the fortunes, and the fate of the most distinguished individuals shall pass before us, continuously and successively, in connection with the origin, the aggregate progress, the glories, the pageants, and the vicissitudes of nations.

Let us study, with more than cotemporary interest, the brilliant biographies of Achilles and Agamemnon, of Julius and Augustus Cæsar, of Plato and of Aristides, of Seneca and of Cicero, of Regulus and of Brutus, of Alfred and of Shakspeare, with the influences of their individual characters on the drama of their cotemporaries, on the history of their nations, and on human civilization.

Let us, in short, having already pictured a beautiful and correct panorama of the whole earth, and realized, as naturalists, with scientific accuracy, the present entire simultaneous existence of our most wonderful little planet, now superadd the idea of time. Time past and passing.

Let us observe the phenomena of its passage, the constant revolutions of the seasons, the succession of generations, the lapse of ages on the whole scene of terrestrial existence.

If you will not neglect the landscapes of the old empires, floating in a broad and vivid panorama below us, I will continue some further general reflections on the natural history of man.

## PHOTOGRAPHY, OR PHOTOGENIC DRAWING, THE CALOTYPE, DAGUERREOTYPE, &c.

### CHAPER I.

ANALYSIS OF THE PRISMATIC SPECTRUM—THE REAL PHOTOGRAPHIC AGENT—EARLY HISTORY OF THE ART.

Photography, or the art of drawing by the solar beams, whether direct or reflected, is one of those splendid modern discoveries which shed a peculiar and pre-eminent lustre on the history of scientific research during the last few years. It dates, as an art, from nearly the same epoch which gave to the world the beautiful results of the Electrotype; and these two elegant and interesting processes, consisting in a triumph over Light on the one hand, and over Electricity on the other—the two most subtle and mysterious agents in the universe—constitute the latest important contributions of modern scientific discovery to the purposes of the fine arts.

The improvements in Photography are daily increasing in interest; new processes are constantly emerging to light, and the path of research which it has opened up to us, promises to lead to numerous collateral discoveries of great value. Even already it has led to important results connected with the influence of light as a chemical agent, which were never contemplated by those who engaged in the inquiries, and science has been largely indebted to a host of photographic amateurs for their zeal and indefatigable diligence in well-directed experiment. We cannot, in a popular and discursive work like the present, enter into much of the theory of the subject, or even enumerate one-half of the multiplicity of processes for varying or improving the art, which have been given to the world by as many different authorities. We hope, however, in a few chapters, to present the reader with sufficiently explicit details to enable him, not only to understand the principles, but even to practise the manipulation with tolerable certainty of success. We cannot conceive a more elegant amusement for those who have a little leisure to devote to such subjects, as some very beautiful results may be produced with apparatus and materials of the simplest and cheapest description. Indeed, it is possible for amateurs, with a very limited command of apparatus, to not only practise the art with gratification to themselves, but even, by varying the experiments and simple materials employed, to strike out new discoveries and improvements which may be of the highest importance to science.

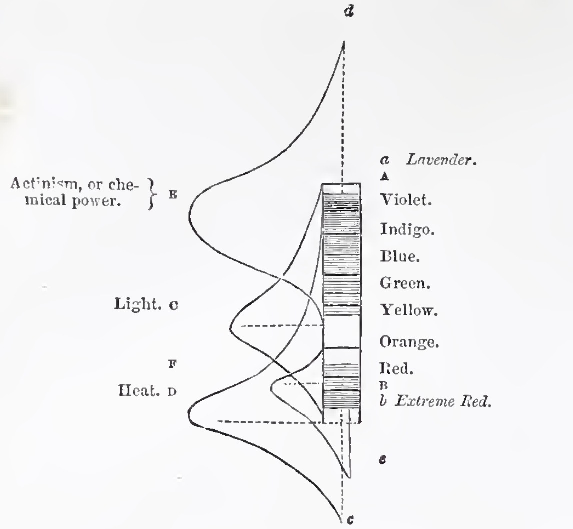
The term photography is derived from two Greek words, φως (phōs) *light*, and γραφειν (graphein) to *write* or delineate. The term daguerreotype, by which it is popularly known, applies to only one branch of the art—that in which silverized plates are employed to receive the image impressed. The name of talbotype, or calotype, is given to those processes, invented or patented by Mr. Talbot, which communicate the impression to paper. Several other substances, such as plate-glass, porcelain, and surfaces of polished steel, have been employed to receive the impressions, and a great variety of new processes have been introduced, to which have been given an equal variety of characteristic names, as the chromatype, ferrotype, fluorotype, chrysotype, catalysotype, &c.; but few of these later discovered processes will call for our special attention, except those by which surfaces of plate-glass are prepared to receive the solar impression. This, as we shall afterwards see, has hitherto been most successfully done by means of a singular and lately-discovered substance termed collodion, a solution of gun-cotton in ether; and the plate-glass presents a surface so exquisitely smooth and polished, while it is at the same time so much less costly than the silver plates of Daguerre, that it promises, in course of time, to be generally employed for the purpose of receiving the photographic image.

Mr. Robert Hunt, professor of mechanical science in the Museum of Practical Geology—a gentleman who has contributed largely, both by his writings and discoveries, to advance the progress of photography—has justly and picturesquely remarked, that, in this delightful art, "the sunbeam is our pencil, and certain delicate chemical preparations form our drawing-board." Neither the paper, nor the silver surface, nor the glass, is the actual recipient of the beautiful picture impressed; these may be necessary to the effect produced, as, for instance, the presence of the organic matter of the paper; but, properly speaking, the "drawing-board," to use Mr. Hunt's term, is the delicate chemical preparation with which the surfaces have previously been washed or coated. We may add, that not even the light itself, in the strict meaning of the word, is the agent which produces the picture; and therefore, the term photography, or "the art of drawing by light," is really a misnomer. The active agent of the process exists in the solar rays, but it is not the light, or luminous principles of these compound rays, by which the photographic effect is produced. And neither is this effect occasioned by the calorific, or heat-producing rays, which, as is well known, exist in the prismatic spectrum in a state of separation from the light. However strange it may seem, it is neither to the light nor to the heat of the solar rays that we are indebted for the beautiful results of photography, but to another mysterious power or principle existing in combination with the light and heat of the sun, to which has been applied the appropriate name of Actinism—a term derived from the Greek word ακτιν (aktin), *a sunbeam*, and signifying merely the influence of the sun's rays, or *ray-power*, without involving the assumption of any theory on the subject.

The composition and coloured refraction of the sun's rays have been explained in a previous chapter of this work (p. 321). We consider it therefore unnecessary to repeat the remarks or illustrations there given. We may observe, however, that below the ordinarily visible red, or least refrangible ray, another ray of a deeper red, distinguished as the *extreme red*, or *crimson* ray, may be detected, by examining the prismatic spectrum through a deep blue glass; and, by throwing the spectrum upon a piece of yellow paper, another ray appears at the violet extremity, named, by Sir John Herschel, the lavender ray. The spectrum, therefore, as produced by the refraction or decomposition of the sun's rays in the manner previously explained and illustrated, at p. 321, exhibits, when fully analysed, a wonderful variety of properties, of which the following diagram will give a sufficiently accurate idea.

In this diagram, the shaded portion represents the colours as they occur in the decomposed solar beam; the space included between A and B exhibits the Newtonian spectrum, and *a* and *b* are the rays which Sir John Herschel has added, thus increasing the number of the different perceptible colours from seven to nine; but all of which, as Sir David Brewster has

shown, are really reducible to three primary colours—red, yellow, and blue. The curved lines in the engraving represent the relative amount of *actinism*, *light*, and *heat*, in different parts of the spectrum. It will be observed that the actinism




is greatest at E, and ceases at *d* and *e* towards either extremity. At the point of greatest light, C, which is in the yellow ray, there is absolutely no actinic or photographic influence. At F, however, near the point of greatest heat, D, the actinic or chemical influence is sensibly felt; but this is ascribed by M. Claudet to the yellow rays being not merely passive or inert as regards actinic power, but having a positive destructive influence on any effects produced by the actinic rays. Mr. Hunt, however, oberves, that this second apparent maximum of the actinic power may be "eventually proved to be a function of heat, since we know that calorific power will produce chemical change even when it is exercised as a radiant force."

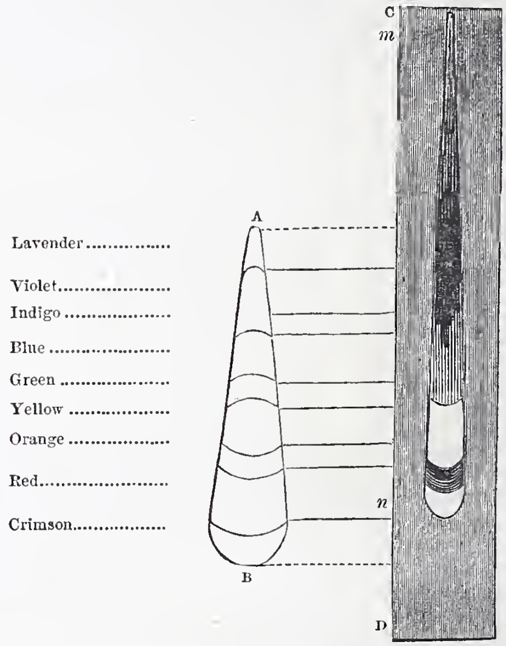
The different heating powers of the various rays were determined by Sir William Herschel and Sir Henry Englefield, who placed a delicate thermometer in each ray, and obtained the following results:—

| | | | |
|---|---|---|---|
| In the blue ray,.........in 3′ | the thermometer rose from 55° to 56°, | or | 1° |
| In the green ray,........in 3′ | ............................from 54° to 58°, | or | 4° |
| In the yellow ray,.......in 3′ | ............................from 56° to 62°, | or | 6° |
| In the full red ray,.....in 2½′ | ............................from 56° to 72°, | or | 16° |
| In the edge of red ray, in 2½′ | ............................from 58° to 73½°, | or | 15½° |
| Quite out of visible light, in 2½′ | ............................from 61° to 79° | or | 18° |

We thus observe that the *yellow*, which is the most luminous ray, has only a small heating power, while the greatest actinic or photographic power exists at that point of the spectrum where the light and heat are least sensible, and even, like the heat at the other extremity, extends a considerable distance beyond the spectrum entirely, producing effects on photographic paper where the rays of the sun are absolutely not visible.

These different properties of the solar rays may be strikingly illustrated by experiment. For instance, glass stained with oxide of copper, and washed on one side with a colourless solution of alum, freely admits the light rays, but abstracts no less than 95 per cent., or almost the whole of the heat rays. On the contrary, a slice of obsidian or black mica, which almost totally intercepts the light, is found to have little or no effect in obstructing the passage of heat. We can isolate, in like manner, the chemical and luminous principles of the sun's rays. If we take, for instance, a sheet of paper prepared for photographic purposes, so as to be exceedingly sensitive to the solar influence, and place over it, so as to cover it completely, a glass stained of a pure yellow by oxide of silver, it may be exposed to the strongest sunshine without exhibiting any alteration of colour; but if we expose the same sheet, covered with a dark-blue glass, such as is usually prepared with the oxide of cobalt, and which must intercept a considerable quantity of light, it will now be found to darken as rapidly under the influence of the solar rays, as if it were exposed to their full and direct action without the intervention of any medium whatever.

The same remarkable facts may be illustrated by throwing the prismatic spectrum itself upon any photographic surface; that is to say, upon a sheet of paper or glass, or any other substance rendered sensible to light by processes hereafter to be described. When this is done, there is always a faint-diffused light thrown over the whole of the paper or other photographic surface, which, as well as the part of the surface on which the spectrum falls, is all more or less discoloured or darkened by the influence of the solar rays—two points only excepted; and these points, let it be observed, where absolutely no change occurs—where the paper, if that be the substance employed, remains positively white and unaltered,—are precisely the points of maximum light and heat—the yellow and crimson rays. This is a most striking and conclusive proof that the actinism or chemical power of the sunbeam is not only perfectly distinct from its luminous and calorific powers, but that it is in some measure antagonistic to both. The accompanying shaded wood-engraving will serve to illustrate




this very remarkable principle. If the luminous spectrum, A B, is supposed to be projected on the sheet, C D, as indicated by the parallel lines, the chemical radiations, having a higher refrangibility than the luminous rays, will extend upward beyond the spectrum to *m*, producing a decided discolouration of the paper where no luminosity is visible. The whole sheet, at the same time, will be partially darkened by the chemical influence of the diffused light. The only parts of the paper which remain uncoloured, are those which correspond to the orange and yellow rays, and to a point at a little distance below the red ray. Where the red ray itself falls, a tinting of red or pink is observed; the green, being a mixture of yellow with blue, produces but a faint photographic impression on the paper.

Having thus explained the remarkable actinic or chemical power of the sun's rays, as distinguished from their luminous and heating power, it will be apparent that the term photography, implying the action of light alone, is really, as already stated, a misnomer. Indeed, so far is even the combined influence of light and heat from producing what are known as the photographic effects, that the farther we advance from our own latitudes towards the tropics, the more difficult does it become to obtain satisfactory pictures by the solar influences. To some of our readers, the fact may be equally

new and surprising, that, under the resplendent light and burning suns of the equator, a longer period is required for impressing a photograph than either in London or Paris. In like manner, even in our own latitudes, photographs are more readily obtained in the months of April and March, than in June, July, and August. In the latter months, as well as in tropical climates, the light of the yellow ray and the heat of the red ray predominate over the actinic influence, and thus, to a certain extent, the photographic effect is neutralized. It has likewise been observed that the morning sun, between the hours of eight and twelve, produces much better effects than are obtained after the hour of noon, although the hottest part of the day is generally about two o'clock.

It would, therefore, be desirable to substitute for the term photography, some such word as actinography, or even heliography. The latter was the term introduced by Niepce, the father of the photographic art in France, and signifies merely *sun-drawing*—a term which expresses the simple fact, without involving a theory. Although, however, the term photography involves a positive misconception—unless we consider the Greek word *phos* to embrace in its meaning a property of the solar ray with which the Greeks were unacquainted—the name has been so generally adopted, and is now so thoroughly established, that it will not be found an easy matter to replace it in common use, or even in philosophical treatises, by any other term. We shall, therefore, continue to use it in our subsequent remarks, having placed the reader sufficiently on his guard as to the error implied in its literal and primary signification.

The blackening effect of the sun's rays upon chloride of silver—or, as it was termed by the alchemists, horn-silver, from its resemblance to a horny substance when fused and congealed—was known so early as the middle of the sixteenth century. This effect was found to be produced when the horn-silver was exposed to ordinary daylight; and was, by the sanguine gold-hunters of the age, regarded as the actual commencement of the transmutation of the silver into the finer metal. It was not, however, until the beginning of the present century, when chemistry had ceased to be alchemy, and had become a science, that any direct attempts were made to obtain photographic pictures by the agency of the solar light on the salts of silver. The earliest recorded attempts of the kind are those of Wedgwood, the celebrated porcelain manufacturer, and Sir Humphry Davy, published in the Journal of the Royal Institution of Great Britain in 1802. These eminent philosophers, by spreading on paper or white leather a solution of the nitrate or chloride of silver, succeeded in copying semitransparent objects, as leaves, flowers, feathers, &c.; but they did not succeed in obtaining a preparation sufficiently sensitive to manifest any impression in the subdued light of the camera obscura; and they ceased to prosecute their photographic researches, before they had devised that essential part of the process—a method of rendering permanent the impressions received. The paper, which was published by Mr. Wedgwood in the journal above mentioned, is entitled "An Account of a Method of Copying Paintings upon Glass, and of making Profiles by the Agency of Light upon Nitrate of Silver; with Observations, by H. Davy." It contains a variety of interesting suggestions, and states, among other facts ascertained, that the blue and violet light were found to produce the most decided and powerful effects. The following short extracts from this paper are interesting, as showing the results of the earliest experiments in photography:—

"When the shadow of any figure," says Sir H. Davy, "is thrown upon the prepared surface (of white paper or white leather, moistened with solution of nitrate of silver), the part concealed by it remains white, and the other parts speedily become dark. For copying paintings on glass, the solution should be applied on leather; and in this case it is more readily acted on than when paper is used. After the colour has been once fixed on the leather or paper, it cannot be removed by the application of water, or water and soap, and it is in a high degree permanent. The copy of a painting, or the profile, immediately after being taken, must be kept in an obscure place; it may, indeed, be examined in the shade, but in this case the exposure should be only for a few minutes; by the light of candles or lamps, as commonly employed, it is not sensibly affected. No attempts that have been made to prevent the uncoloured parts of the copy or profile from being acted upon by light, have as yet been successful. They have been covered by a thin coating of fine varnish, but this has not destroyed their susceptibility of becoming coloured; and even after repeated washings, sufficient of the active part of the saline matter will still adhere to the white parts of the leather or paper, to cause them to become dark when exposed to the rays of the sun. Besides the applications of this method of copying that have just been mentioned, there are many others; and it will be useful for making delineations of all such objects as are possessed of a texture partly opaque and partly transparent. The woody fibres of leaves, and the wings of insects, may be pretty accurately represented by means of it, and in this case it is only necessary to cause the direct solar light to pass through them, and to receive the shadows upon leather.

"The images formed by means of a camera obscura have been found to be too faint to produce, in any moderate time, an effect upon the nitrate of silver. To copy these images was the first object of Mr. Wedgwood in his researches on the subject; and for this purpose he first used nitrate of silver, which was mentioned to him by a friend as a substance very sensible to the influence of light; but all his numerous experiments as to their primary end proved unsuccessful. In following these processes, I have found that the images of small objects, produced by means of the solar microscope, may be copied without difficulty on prepared paper. This will probably be a useful application of the method: that it may be employed successfully, however, it is necessary that the paper be placed at but a small distance from the lens."—(*Davy.*)

"Nothing but a method of preventing the unshaded parts of the delineations from being coloured by exposure to the day is wanting, to render this process as useful as it is elegant."

Here it was that the researches of Wedgwood and Davy were arrested in 1802. The results of their most successful experiments were evanescent; they had not succeeded in hitting on any of the simple processes by which the photographic image is now rendered enduring, and therefore they considered it useless to pursue the subject farther, till some such process should be discovered. From that time no attempt appears to have been made to improve and render permanent the photographic impression, till M. Niepce, of Chalons, on the Saone, directed his attention to the subject. The first experiments of this gentleman were made about the year 1814, but they seem to have been little successful; and it was not till many years afterwards, when he became accidentally acquainted with M. Daguerre, that the researches were prosecuted with that success which ultimately crowned the united efforts of the two inquirers. M. Daguerre had, for some time previously, been labouring to fix the images obtained by the camera obscura, and in December, 1829, this gentleman and M. Niepce, attracted by a similarity of tastes and pursuits, drew up a deed of copartnery for sharing their discoveries with each other, and investigating the subject together.

Both of these diligent experimentalists, in previously pursuing their inquiries separately, had struck out improvements on the methods of operation devised by Wedgwood and Davy. The material first selected by Daguerre was *paper*, impregnated with the chloride or nitrate of silver; but, in operating with this material, he seems to have advanced but little beyond the imperfect and fleeting results obtained by his English predecessors in the same department of inquiry. M. Niepce had been rather more successful, and, in 1827, he presented a paper to the Royal Society of London, detailing the results, but not the *rationale*, of his process, which he termed heliography. This memoir, as it kept the process a secret, could not, in accordance with the laws of the society, be received; but it was accompanied with several designs on metal, which proved that the author was then acquainted, not only with a method of forming sun-pictures, superior in beauty and fidelity to any previously produced, but likewise with the all-important secret of rendering the impressions permanent. The

substances used by Niepce for receiving his sensitive preparations, were glass, planished tin, and copper plated with silver.

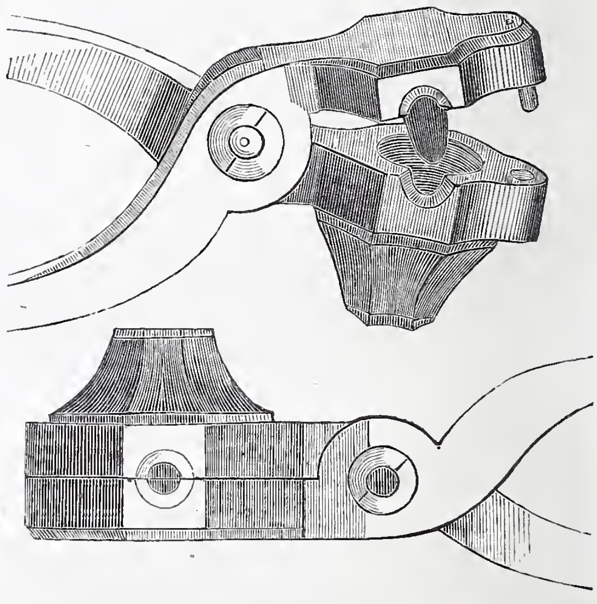
It is to be presumed that M. Daguerre obtained from his distinguished colleague the rudiments of that successful process, which he afterwards brought to perfection, and which was announced to the world early in January, 1839. This was the date of the first publication of the beautiful results of the Daguerreotype; but not till the July following was the process published, when a bill had been passed, securing to Daguerre himself a pension of 6000 francs for life, and to M. Isidore Niepce, the son of the gentleman, associated with him in these pursuits, a pension for life of 4000 francs, with one half in reversion to their widows. It being presumed that "the invention did not admit of being secured by patent, for as soon as published all might avail themselves of its advantages," these liberal pensions were granted by the French Government, under the late Louis Philippe, for "the glory or endowing the world of science and of art with one of the most surprising discoveries that honour their native land."

In the meantime, experiments leading to similar results, although by a different process and the use of different materials, were made by Mr. Fox Talbot in this country, so that to this gentleman undoubtedly belongs the honour of independent invention. It was on the 31st of January, 1839, immediately after the announcement of M. Daguerre's success, but six months prior to the publication of his process, that Mr. Talbot communicated to the Royal Society his photographic discoveries, and in the following month of February he published the details of his process. He stated, in his memoir to the Royal Society, that he had devised the general features of his method some time previous to the spring of 1834, when he began to put it in practice, and when he was entirely ignorant of what had been done on the continent. His process, moreover, which consisted in impressing and fixing the image on prepared paper, was different from that of Daguerre, who employed silverized plates.

Although the Government of France, with an enlightened liberality which did it the highest honour, purchased for the public in that country the free and unfettered use of the daguerreotype process, it is to be regretted that, in this country, the progress of photographic improvements, and more especially their general use and application, have been much obstructed by exclusive patent rights. M. Daguerre's process was no sooner published in 1839, than a patent was taken for it in England by Mr. Berry, who calls it, in his specification, "A new and improved method of obtaining the spontaneous reproductions of all the images received in the camera obscura;" and in 1842, after Sir John Herschel and others had contributed several important improvements in the methods of procuring permanent delineations on paper, Mr. Talbot, freely availing himself of these, included them in a sweeping patent with his own discoveries. The same gentleman has subsequently taken different patents for successive improvements or novelties in the art, to some of which his claims to become a patentee are exceedingly doubtful; and while he has confessedly the merit of inventing many ingenious processes, it must be admitted that he has exhibited a grasping spirit of monopoly which seems to show that he is animated by other motives than those of a disinterested regard for the promotion of science and the arts. On the part of a person in limited circumstances, no reasonable objection could be urged to such a mode of proceeding, legitimately carried out, with the view of improving his condition by the fruits of his industry and ingenuity; but it is a totally different case when a gentleman, already possessed of an independent fortune, and claiming the title of philosopher, not only seeks pecuniary advantage, by one patent after another, for his own admitted discoveries, but even evinces a disposition to appropriate to his own exclusive advantage the discoveries of other inquirers who have given them freely to the world. This, as we shall afterwards see, has been too much the case with Mr. Talbot, who has been regarded, in consequence, with anything but friendly feelings by the zealous and disinterested amateurs of the art; and an attempt which was lately made to establish a photographic society, failed entirely from the somewhat unreasonable claims, founded on his so-called patent rights, which that gentleman insisted on rigorously enforcing. At the same time it gives us pleasure to state, that, in subsequent negotiations connected with this subject, Mr. Talbot has manifested some disposition to forego the extreme rigour of his claims, and to come to a more liberal arrangement, not incompatible with the formation of such a society of amateurs as that proposed to be established.

## BECKWITH'S IMPROVED BULLET-MOULD FOR THE MINIE RIFLE.

We have given, at page 509, an account, with accompanying engravings, of the Prussian Needle-Gun, which, although highly ingenious, and undoubtedly presenting some advantages, cannot be adopted without a complete change in our fire-arms, the expediency or policy of which, while improvements are rapidly succeeding each other, is at least doubtful. The system adopted in the Minié rifle appears to be the safest for adoption at present, if not positively the best; because it admits of our employing the ordinary rifle, with greater facility of loading, on account of the ball being smooth, while a vastly increased range is obtained. We may remark, by the way, that the "Minié rifle" appears to be a misnomer, and that, if we are justly informed, the merit of the improvement in which its value consists is due to Captain Delvigne, who had taken out a patent for it in France. It ought, therefore, to be termed the "Delvigne rifle."



The distinguishing merit of this invention consists in the shape of the ball or bullet, of which a full-sized sketch is annexed. The reader will observe that it is made hollow at the base, or flattened end, to admit of the insertion of a thin wrought-iron cup, as shown in the sketch. The effect of this arrangement is, that when the explosion takes place, it forces the cup into the yielding ball, which is thereby suddenly expanded, so as to assume the shape of the groove or rifling in the barrel, although it had previously been smooth, so as to be driven home with ease. The windage is thus annihilated, and an almost incredible range is obtained.

Figs. 1 and 2 exhibit Mr. Beckwith's improved mould for casting this bullet: in the former, it is shown open; in the latter, shut. The improvement consists in making the runner at the side of the ball, instead of at the point, while the core is made a fixture. By this arrangement the ball is rendered more solid and easier cleaned from the runner, while greater accuracy and precision are obtained in the casting.

## NATURAL PHILOSOPHY AND CHEMISTRY.

### CHAPTER XVII.

#### ON THE PRESENT STATE OF VOLTAIC ELECTRICITY AND ELECTRO-MAGNETISM.

PART I.—VOLTAIC ELECTRICITY.—(*Continued.*)

49. As we have used, and shall have further occasion for using, certain terms which have been introduced by Faraday with a view to the better understanding of the various phenomena attending Voltaic action, it is proper here to inform the reader that the term "ïon," used previously, means any element which being separated from any other element by electric action, proceeds to, or appears at, the positive or negative wire, or other electric conductor in connexion with the battery, or at the positive or negative plate of the battery itself; that the wires or conducting substances, in connexion with the plates of the battery, are denominated "electrodes," because they afford a passage to the electricity developed in the pile; that the terms "Anion," and "Cathion," denote respectively the negative and positive ïons; the term "Anode," that side of the fluid interposed between the electrodes, where the electricity enters; and "Cathode," that side from which it issues, or makes its exit.

50. Next in importance to our knowledge of the definite nature of Voltaic decomposition, is our correct apprehension of the nature of those laws which govern the transmission of the electric current through liquid conductors, as well as of the influence which the quantity or volume of the conducting liquid exerts over the intensity of electricity in motion.

51. Much has been written upon this subject, and philosophers have differed widely as to the nature and amount of resistance presented by various conducting fluids of different conducting powers, and different dimensions; it would appear however, that the conclusions of M. Marianini, which have been confirmed by Matteucci, and others of equal scientific celebrity, rest upon a firm basis, and therefore deserve to be briefly noticed; many of the experiments of these philosophers have been repeated and varied by the writer, and have generally led to similar deductions.

52. It appears that the velocity of the current is much weakened by the thickness of the liquid volume it has to traverse, and that the loss is nearly in proportion to the increase of that thickness, whatever may be the nature and energy of the Voltaic pairs; but that in proportion as the liquid is endowed with greater conductibility, so is the weakening influence of the thickness diminished. Matteucci has established these results by a more exact method, and has further ascertained that the retarding effect occurs in a proportion more rapid than that in which the increase of thickness is varied.

53. The conclusions drawn from trial of the influence of *length* of the liquid volume, are the following:—

1st, The intensity of the current propagated through a liquid conductor, increases generally in proportion to the diminution in length of the liquid volume it has to traverse.

2d, When the pile has a very feeble power of production and propagation, it is found that on varying the number of pairs, the increase of intensity by diminution of thickness of the interposed liquid, is not in the same proportion.

3d, That this increase is as much less as the liquid is a better conductor, and the number of pairs greater.

4th, It has been found that, by increasing the number of plates, and employing a good conducting liquid, a maximum intensity may be obtained to which the resistance of the liquid volume is nothing, and that the limit is arrived at sooner, in proportion as the liquid is a better conductor.

54. But the foregoing conclusions differ when the force of the pile is varied; and the results of careful experiments under such circumstances show, that when the pile has a very great power of production and propagation, the intensity produced by diminution in length of the liquid volume, increases in proportion to the increase of the number of pairs.

55. Now, if we increase the surfaces of these pairs, we shall see that, in proportion to the intensity of current, varied with the extent of surface, the effects vary likewise by diminution in length of the interposed liquid in proportion as the surface of the pairs is extended, and as the liquid is improved in condition.

56. In the experiments which led to the preceding results, only one of the dimensions of the liquid volume was varied, the other two being kept constant; but if the latter be now varied, keeping the length constant, the results will materially differ; for instance, by increasing the width of the liquid volume, its length and height being constant, the intensity of the current traversing it increases up to a certain limit of this width: for this the battery must be feeble; beyond this limit, the intensity of the current diminishes; and the feebler the pile, and the greater the number of pairs, the sooner is this limit attained.

57. So far the width and length only of the liquid conductor have been changed; but now, if we examine the influence of the height of the liquid, we shall find the following to be the general result:—"The limit at which the increase of intensity, by augmentation of height of the volume itself, stops, is attained as much sooner as the pairs are more numerous, and the conductibility of the liquid better; varying the force of production and propagation in the pile, the results vary.

58. Combining the results of a number of experiments upon difference of height, we are justified in drawing the following conclusions:—

1st, When the productive and propagating force in the pile is great, either from the nature of the liquid or the extent of the pairs, the intensity of the current propagated by different liquid volumes, increases in proportion to these volumes, and in a ratio as much more elevated as the pairs are more numerous, and the liquid a better conductor.

2d, We have seen that with feeble piles we attain a volume-limit, beyond which the intensity of the current diminishes. This volume-limit is attained sooner with a pile of a greater number of pairs, and a good conducting liquid. When the pile is energetic, this limit becomes less perceptible, and that in proportion to the force of the pile, the number of pairs, and the conductibility of the liquid.

3d, This volume-limit is also modified by the height of the liquid; the same volume of a certain liquid which is limited with a certain pile, when the height of the liquid is one inch, is no longer limited, *cæteris paribus*, when the liquid is three inches high.

4th, This augmentation of intensity caused by the increase of the liquid volume from which the current is propagated, is as much stronger with the same pile and equal volumes, as the height of the liquid is greater; and this influence of height increases with the volume.

5th, The advantage derived from the increased height of the liquid column, with equal volumes is so great, that with batteries consisting of from twenty, thirty, to forty pairs, and a difference in the height of the liquid column of from one to three inches, less intense currents are obtained than from a battery of a considerably less number of pairs, whose current traverses a higher column.

6th, The advantage obtained from the increased height of the column is such, that in batteries consisting of the same number of pairs, we have, with a volume represented by 40, two inches high, a more energetic current than with a volume represented by 80—the height of the column being only one inch.

59. When we consider the results derived from the preceding experiments, it becomes evident that the increase in the number of pairs in the compound battery is not alone necessary for the due development of effects of intensity; but that, with a view to the production of the highest degree of electric energy, certain rules in relation to the adaptation of the volume of the conducting liquid, with respect to width, length, and height, must be strictly adhered to, involving, of course, the form and superficial dimensions of the metals employed in the series.

60. But we must not alone look to the attainment of the most advantageous proportions between the length, height, and width of the interposed electrolyte; for the nature and conducting power of the electrolyte itself, according to the special purposes for which the Voltaic arrangement is designed, as well as the particular positive and negative metals employed, become of equal importance, inasmuch as it has been found that the metals when brought into contact with different liquids, hold a very different position in the positive scale, varying in this respect to so great an extent that the metal which with one liquid is positive to most others, becomes, with a different liquid, negative to most—a result which depends apparently upon the varying inductive action upon the same or different metals, of the various electrolytes employed: an action which varies as much in any one electrolyte—according to its peculiar conducting power, that is, according to the attractive forces of the elements of which it is composed—as it does in any two dissimilar liquids in the scale. The reader will comprehend those important differences more easily by inspection of the following table, in which the exciting fluid is placed at the head of each column, and the metals are arranged according to the degree of their positive condition:—

| Hydrochloric Acid. | Dilute Nitric Acid. | Strong Nitric Acid. | Solution of Caustic Potash. | Yellow Hydro-sulphuret of Potassium. |
|---|---|---|---|---|
| Zinc. | Zinc. | Cadmium. | Zinc. | Zinc. |
| Cadmium. | Cadmium. | Zinc. | Tin. | Copper. |
| Tin. | Lead. | Lead. | Cadmium. | Cadmium. |
| Lead. | Tin. | Tin. | Antimony. | Tin. |
| Iron. | Iron. | Iron. | Lead. | Silver. |
| Copper. | Nickel. | Bismuth. | Bismuth. | Lead. |
| Bismuth. | Bismuth. | Copper. | Iron. | Antimony. |
| Nickel. | Antimony. | Antimony. | Copper. | Bismuth. |
| Silver. | Copper. | Silver. | Nickel. | Nickel. |
| Antimony. | Silver. | Nickel. | Silver. | Iron. |
| Platinum. | Platinum. | Platinum. | Platinum. | Platinum. |

61. In the preceding table we have merely set forth the electrical conditions of the same metals in relation to one another, when in contact with different fluids; but if we select any one of the metals in that table, and compare its electro-motive effects when brought into voltaic connexion with any other metal in the table—two fluids being connected with each pair, and used throughout the series—we shall find the most extraordinary differences in the amount of electro-motive force developed, as well as in the direction of the current.

62. For instance, if we compare the action of dilute sulphuric acid, and of water, upon a zinc-platina, a zinc-silver, a zinc-copper, and zinc-tin circuit, we shall find that, in the first, (upon the first immersion,) the dilute acid has a greater electro-motive force than the water; in the second, the water has a greater force than the acid; in the third, the water has the ascendancy; and in the fourth, the same. With a solution of chlorine, and with water: the chlorine has the ascendancy in the first; the water in the second; the water in the third; and in the fourth, the forces are equal, and therefore neutralized. With dilute sulphuric acid, and iodide of potassium (1 part by weight to 4 of water), the iodide has the ascendancy in the first; the acid in the second; the acid in the third; and the iodide in the fourth. And with dilute sulphuric acid, and a saturated solution of chlorhydrate of ammonia, the ammonia exceeds in the first; the ammonia in the second; the acid in the third; and the ammonia in the fourth.

63. In those combinations in which zinc, iron, or tin, forms the positive metal, even in some in which amalgamated zinc holds that position, the water holds the ascendancy over the dilute hydrochloric acid; it also preserves the ascendancy, in most cases, over sulphuric acid, even in a greater degree, with the combinations zinc-platinum and zinc-tin, and yet sulphuric acid is no electrolyte; neither is nitric acid an electrolyte, and, notwithstanding, it so changes the electro-motive force, that in the zinc-platina circuit it has the ascendancy over water: but in other combinations, with zinc or tin, as the positive element, it is inferior to it. Ammonia is not an electrolyte, but in all combinations with iron and tin as + element, it is always inferior to water; on the other hand, in those with zinc amalgamated, or pure, (copper excepted) it has, for the most part, the ascendancy: it is, therefore, not correct to assert, as has been frequently done, that electrolytes—properly so called—are alone capable of changing the electro-motive force.

64. It is here worthy of remark, as furnishing one out of many strong arguments against the chemical theory, that although chlorine has unquestionably a stronger affinity for zinc, iron, and tin, than oxygen possesses, nevertheless, in circuits in which one of these metals forms the positive element, hydrochloric acid does not act more strongly, but more weakly than water; it also acts more weakly than sulphuric acid in combinations of amalgamated zinc and platinum, or silver.

## CHEMISTRY OF INORGANIC NATURE.

### CHAPTER VI.

BORON—SILICON—SULPHUR—SELENIUM—CHLORINE—IODINE—BROMINE—FLUORINE.

The elements which fall to be enumerated in this chapter are less plentifully distributed in mineral nature than some of those already described; but although they very rarely present themselves in a separate state, their compounds are in general well known and valuable in the arts of life. They have each, moreover, their characteristic properties, which render them objects, even of popular interest. The first which presents itself, as most nearly allied to carbon, described in our last paper under this general head, is

Boron.—This is the basis of a substance which has been long and extensively used in the arts and in medicine, under the name of *borax.* It is found abundantly in Thibet and in South America, but in a state too impure to be used without refining. This was long a secret process practised profitably by the Venetians and Dutch, who imported the crude salt into Europe under the name of *tincal.*

Borax has a sweetish taste, and is "soluble in twelve parts of cold, and two parts of boiling water." Its crystals are transparent, but effloresce and become opaque in a dry atmosphere; and they appear luminous by friction in the dark. It melts at a heat a little above that of boiling water, and gives out its water of crystallization, after which it forms a spongy mass, well known as calcined borax. When further heated to ignition, it passes into a glassy-looking substance, known as glacial borax.

If a quantity of glacial borax, finely powdered, be intimately mixed with a tenth of its weight of powdered charcoal, and the whole be heated intensely in an iron tube, closed at one end, a black powder is obtained. This being washed several times with hot water, then with hydrochloric acid, (spirit of salt) and finally with water, assumes a blackish-olive colour: it contains some charcoal, and another ingredient, which is *boron.** The blackness is chiefly derived from the charcoal: the boron in a state of purity is an opaque-brownish olive powder, infusible, and not volatile in any temperature to which it has as yet been exposed. When heated in air it bears all degrees of temperature under 600° without change; but above that heat it takes fire, and combines with

* The boron obtained in this way is sufficiently pure for ordinary experiments, but, if wanted absolutely pure, boracic acid must be decomposed by potassium. The decomposition is thus effected: Two parts of potassium are mixed with one of boracic acid, previously fused and powdered; the mixture being then put into a copper tube, and raised to a temperature of 300°, it suddenly becomes red-hot. After cooling, the product is to be washed with warm water: it is then pure boron.

the oxygen of the atmosphere. If burned in pure oxygen, it throws off bright scintillations, like iron, when burning under the same circumstances. The compound, which is formed during the combustion, contains in whole numbers 31 of boron, and 69 of oxygen, in the 100 parts. It possesses the properties of an acid, and is therefore called *boracic acid;* and this, when combined with soda, forms the borax of commerce.

Boracic acid is obtained in unlimited quantity from the lakes of Tuscany: the water requires simply to be evaporated until the acid solution has been sufficiently concentrated to afford crystals. The acid thus obtained is chiefly taken to M. Payen's works at Marseilles, where it is manufactured into borax. Native boracic acid is also found among the volcanic products of the Lipari Islands, where it has likewise been collected for the manufacture of borax. It exists also in the waters of some hot springs, as in those of Sasso, in the Florentine territory, and in some minerals as datolite and boracite.

Dry borax, at a high temperature, has the remarkable property of melting and vitrifying the metallic oxides into glasses of different colours. On this account it is a most useful reagent for the blowpipe. With oxide of chrome, it forms an emerald green glass, and with oxide of cobalt, an intensely blue glass. Oxide of copper tinges it pale-blue; oxides of iron, bottle green; oxide of tin, opal; oxide of manganese, violet; oxide of nickel, pale yellowish green. With the oxides of silver and zinc, and with several of the earths it forms white enamels. Borax, in consequence of this property of vitrifying the metallic oxides, is used to clean the surfaces of metals, in processes of soldering with hard solder, and of welding cast-steel. It is also valuable in the fusion of metals to protect their surface from oxidizement. And, it is worthy of remark, that, when mixed with shell-lac in the proportion of one part to five, borax renders that resinous substance soluble in water, and forms with it a species of varnish.

According to the opinion of several of our most eminent chemists, the next element which naturally falls to be noticed, is the basis of flint or silica—described at p. 424. When the metallic nature of the earths in general was in progress of being ascertained, it was perhaps too hastily concluded that the composition of silica was analogous to others which had been examined. The basis was, in consequence, named *silicium;* but subsequent experiment has failed to establish the metallic character of the base, and, indeed, has rather tended to show that it ought to rank in that class of bodies of which carbon is the type, under the more appropriate name of *silicon.*

Silicon is obtained in a separate state by a rather difficult process, and in very small quantities. It is a dark brown powder, without metallic lustre; does not conduct electricity, and, when first prepared, is combustible in common air and in oxygen gas; but, by exposure to a high temperature, it becomes very hard, and will not burn, even in oxygen gas. In these respects it seems closely allied to boron.

Sulphur.—This element, popularly known as *brimstone,* stands sufficiently well characterized by its brittleness, nonmetallic appearance, and peculiar yellow colour. As a combustible it is universally known. Exposed to a temperature of 218° it melts almost into a liquid; when heated a few degrees higher it becomes tenacious; and, when heated to the temperature of 300° it takes fire, burns away with a lambent blue flame, and leaves no residuum. As the temperature rises, the flame becomes more white, and in pure oxygen gas the combustion goes on with great brilliancy. If, while melted and viscid, sulphur be poured into cold water, it acquires somewhat the consistency of soft sealing-wax, and, in this state, it is very commonly used for taking impressions from seals and medals. When strongly heated out of confact of air, it boils and evaporates; and the vapour emitted, condensing when its temperature is reduced by contact with any cold body, forms the bright yellow powder known as *flowers* of sulphur. It is obtained in this state by a process of distillation, the crude sulphur being put into a cast-iron retort, the beak of which is led into an air-tight chamber, where the vapour is condensed. When the sulphur is melted and poured into wooden moulds, it forms the yellow cylinders known as roll-sulphur. One of these rolls held in a warm hand emits a crackling noise by the fracture of its interior parts, and at length breaks in pieces. When rubbed it emits a peculiar well-known smell, and becomes, at the same time, negatively electric.

Sulphur is one of the few elementary substances which occur in nature in a simple state. It is an abundant product in many parts of the world, especially in volcanic countries, where it is found often in a state of great purity. It occurs in amorphous masses of a glassy lustre when newly broken, and also in crystalline masses, and sometimes in complete and regular crystals. It is remarkable that these crystals are invariably octohedrons with rhombic bases, whereas, when sulphur is melted and allowed to crystallize by cooling, the crystals obtained are oblique rhombic prisms—two forms which have incompatible geometrical relations to each other, and which exemplify very clearly that property denominated *dimorphism.*—See Vol. I., p. 44. The density of the native crystals is also slightly greater than the density of melted sulphur (the former being 207, and the latter 199, taking water as 100).

Native sulphur is brought into this country chiefly from Sicily, where it occurs in beds of a blue clay formation, occupying the central half of the south coast of the island, and extending inwards as far as the district of Etna. These beds are considered by Dr Daubeny of the same age as the gypsum bed of Paris, and therefore more recent than the chalk formation. The quantity of sulphur contained in them seems inexhaustible; England alone imports annually from 15,000 to 20,000 tons of it, and France considerably more.

Sulphur is very commonly found deposited in the fissures of lava near volcanic craters, and is sometimes found in veins traversing granite and mica slate.

Sulphur is also an abundant ingredient in various minerals: iron pyrites and galena—sulphurets of iron and lead—are particularly abundant in some localities; and at one time a large portion of the sulphur used in England was obtained from the copper pyrites of the mines of Anglesey. Iron pyrites exists abundantly in several of our mining districts; and the late interruption of the Sicilian supply of sulphur has had the effect of teaching our manufacturers to depend upon that mineral in a great measure for the sulphur employed in the arts. It is less pure than the fine sulphur of Sicily, and other volcanic districts, being commonly mixed with arsenic and other metallic impregnations, which are difficult to separate.

From the circumstance that sulphur occurs abundantly in nature in an uncombined state, it has been known from the most remote antiquity. From its kindling at a low temperature, it has long been employed for readily procuring fire. Even the preparation of sulphur matches constitutes no inconsiderable branch of industry; and this has been vastly extended of late, by the discovery of a mode of rendering the matches inflammable by friction. This is effected simply by dipping the sulphur matches into a mixture of which chlorate of potash forms the chief ingredient.* Sulphur is sometimes employed for cementing iron bars into stone, and at present it is in repute for taking impressions of seals and cameos. When used for this purpose it is commonly kept previously melted for some time to give the casts the appearance of bronze. The principal consumpt of it, however, is in the manufacture of sulphuric acid, gunpowder, and vermilion.

* Berzelius gives the following as the best composition for these matches:—30 parts of powdered chlorate of potash, 10 of powdered sulphur, 8 of sugar, 5 of gum-arabic, and a little cinnabar to give colour. The sugar, gum, and chlorate of potash, are first rubbed into a paste with a little water, the sulphur is then added, and the whole being thoroughly beaten together, small brimstone matches are dipped in so as to retain a thin coating of the mixture upon their sulphured points: when dry, they are ready for use. Some of the recent lucifer matches contain a very little phosphorus, which increases their inflammability.

When the end of a sulphur match is lighted, the flame emits copious fumes which are a compound of oxygen and sulphur. They are pungent to the smell, and have the property of bleaching various textures, as those of silk, wool, and straw. They have also the property of suddenly extinguishing flame, and for this reason sulphur is sometimes thrown into a chimney on fire with the best effect. These fumes are not only pungent to the smell, and fatal to respiration and combustion, but are intensely acid to the taste; they constitute what is called sulphurous acid—the first of the combinations of sulphur and oxygen. The gas has a strong affinity for water, and the solution which it forms with it is known as liquid sulphurous acid. This, if left exposed to the air, absorbs more oxygen, and passes into sulphuric acid.

This is exemplified on a scale of immense magnitude in the island of Java. On that island is Mount Idienne, a volcano, from which the Dutch East India Company often obtained sulphur for the manufacture of gunpowder. At the foot of this volcano is a vast natural manufactory of sulphuric acid: this is a lake of 450 yards in length, the water of which is warm and intensely sour, pungent and caustic. Towards the south-west, the lake discharges itself and forms a river, in which nothing lives, and which poisons all the vegetation in the district through which it flows. From this account it is clear that the water derives its acidity from its absorbing the sulphurous fume occasioned by the incessant combustion of the sulphur in the volcano. The result is the formation of sulphuric acid in enormous quantity, and by a process strictly analogous to that employed in its artificial manufacture—the combination of sulphur by combustion with the oxygen of the atmosphere.*

Sulphur also combines with hydrogen, forming the highly poisonous and offensive gas, known as sulphuretted hydrogen, and which not unfrequently contaminates the coal-gas supplied to us for illumination. Sulphur and carbon also combine, and form a beautifully transparent and colourless liquid exceedingly volatile, and giving off an odour the most fœtid and nauseous, which it is possible to conceive. Sulphur, likewise, enters into combination with metals, forming sulphurets. But we must return to these compounds individually—several of them are of great importance, and few of them are devoid even of popular interest.

Selenium—This is a rare elementary substance nearly allied to sulphur in its properties, although it in some respects partakes of the nature of a metal. It was discovered by Berzelius in 1817, in the refuse of an oil-of-vitriol manufactory, where it was derived from the iron pyrites employed in the works, and which contain a mixture in very minute proportions of a similar compound of selenium and iron. It has also been found sparingly in combination with several other metals, as lead, cobalt, copper, and bismuth, and with sulphur in the volcanic products of the Lipari Islands. It is separated from its combinations with difficulty, and hitherto only in minute quantities. When obtained free of admixture, selenium, at common temperatures, is brittle, solid, of a reddish brown colour and metallic lustre, without taste or smell. But when finely pounded the powder assumes a deep red, inclined to purple. It softens at the temperature of 180°, is pasty at 200°, and melts at a few degrees above the boiling point of water. When warm, it exhales a strong odour of decayed horse-radish, and is so ductile that it may be drawn into threads, which are red, by transmitted, but gray by reflected, light. It boils at 600°, and, in close vessels, throws off deep yellow vapours, which condense into black metallic-looking drops; but when very large receivers are employed, the vapours are deep red, and condense in *flowers* of the colour of cinnabar. It undergoes no change by exposure to air or water; and, like sulphur, it is a non-conductor of electricity, and a bad conductor of heat.

This remarkable substance which, in its compositions, runs parallel with sulphur, and apparently holds an intermediate place between that element and the metals, has hitherto been known only in the laboratory of the chemist; but there is little doubt that, as soon as we have learned to extract it abundantly from its combinations, it will be found useful in the arts.

The next three elementary forms of matter which come under our notice are not only connected together by the strongest analogies, but have, moreover, one common source—namely, the waters of the ocean. We do not find them existing in an insulated state like sulphur and carbon; they have been eliminated from their combinations by artificial means—two of them, indeed, are of very recent discovery; namely, *iodine* and *bromine;* and *chlorine*, though known since the days of Scheele, (1774,) was not recognised as an elementary body until Sir H. Davy demonstrated its true character.

Chlorine—This, in a separate state, and under ordinary circumstances, is a greenish yellow gas; but when submitted to a pressure of four atmospheres, it becomes a yellow transparent liquid. The gas, if breathed undiluted, is fatal to animal life; yet it does not extinguish flame; on the contrary, various bodies, when immersed in it, take fire spontaneously. A candle burns in it with a red flame; and a piece of phosphorus introduced into it burns with a pale white light. Copper, tin, zinc, arsenic, and antimony, when introduced into it in thin leaves, or reduced to filings, take fire, and combining with the gas form compounds analogous to the *oxides,* and which are therefore named *chlorides*. Mercury also enters rapidly into combination with it, forming chloride of mercury; a substance better known as *corrosive sublimate.* Water absorbs twice its bulk of the gas, and the solution is called chlorine-water. If this solution be exposed to the sun's light it is observed to give off oxygen, and after a time it is found that the solution has attained acid properties: that it has lost the astringent taste which it originally possessed, and has attained, instead of this and other properties, the particular properties of the acid popularly known as spirit of salt, and which, it is plain from this simple experiment, must consist of chlorine and hydrogen in combination.

One of the most remarkable properties of chlorine is its power of destroying all vegetable colours. If a vegetable blue—for instance the blue infusion of red-cabbage—be exposed to its action, the colour is not altered to red, as it would be by an acid, nor to green as it would be by an alkali, but is totally destroyed; and the medium in which the blue was contained, appears colourless, at least so far as the vegetable was concerned. On this account chlorine has been introduced as a powerful agent in the art of bleaching. Thus if unbleached linens be properly exposed to its action, the matter which gives them their gray colour is decomposed, and the linen assumes the whiteness which is natural to its fibres. However, if applied in its pure state, and not sufficiently diluted, chlorine attacks the vegetable fibre, and invariably destroys the strength and texture of the linen, and therefore it is a dangerous agent in the hands of the inexperienced. To render it more safe and convenient of application, it is always tempered by the quiescent affinity of some alkaline base, as potash, soda, or lime. A weak solution of caustic potash, or soda saturated with the gas, affords a "bleaching liquor," which is still used by some bleachers and calico printers in their more delicate processes; but the price of these alkalies has led to the employment almost universally of the "bleaching powder," manufactured to an immense extent in this country and on the continent, under the name of "chloride of lime."

The bleaching property of chlorine consists in its powerful affinity for hydrogen; not only does it combine rapidly with that element in the gaseous state, under the influence of light, but seizes upon it in many of its liquid and solid combinations—as in volatile oils, which it inflames, and in yellow wax, cotton, and flax, which it whitens by decom-

* It may possibly be thought strange that so much oil of vitriol should be manufactured in Britain, when it can be procured ready made in Java; but the acid of the lake is largely diluted with water, and, in the first place, would require to be concentrated by boiling, and, in the next place, it would require to be carried 15,000 miles, which, even though found pure, would cost more than the price at which sulphuric acid can be made at home—namely, three farthings a lb.

posing the matter which gives them colour, and of which hydrogen is reckoned the basis. For the same reason, it is used successfully in destroying malaria, and putrescent miasmata, which all contain hydrogenous matter as their base, and which is seized upon by this energetic element. It is the same affinity for hydrogen which causes the evolution of oxygen gas from water which has absorbed chlorine; the chlorine combines with the hydrogen of the water forming hydrochloric acid,* and liberates the oxygen, the other element of the water.

It was stated that the grand source of chlorine is the water of the ocean. This is an enormous solution of *salt*—a universally known and indispensable article of consumption with the human race, an article indeed which seems to be essentially necessary to maintain the body in a healthy condition. Now this *salt* is a compound of chlorine and a metal; it is in fact a chloride, consisting when pure of 60 of chlorine and 40 of sodium in 100 parts; and whether it be obtained by evaporation of sea water, or be dug out of the salt mines of Wicliczka or Northwich, it has the same composition. It is never indeed found unmixed with foreign matters, but it may be separated from all impurities by appliances of chemistry, which it is not our business in the mean time to describe.

To separate the chlorine from the metallic base with which it is in combination in the salt, it is only necessary to devise a means of subverting the affinity which retains them in union. This can readily be done in the following way: introduce into a glass retort a mixture of three parts of common salt, and two parts of black oxide of manganese, and pour upon the mixture two parts of sulphuric acid diluted with its own weight of water. (A tubulated retort should be used, and the acid should be added at two or three different times to avoid too violent an effervescence.) The heat of a spirit lamp being applied to the retort, the gas will be expelled, and may be collected in bottles inverted in as little water as will answer the purpose, in order to prevent waste by absorption. This is a method of obtaining chlorine from common salt; it is that practised by the manufacturer upon an extended scale; but chlorine may be obtained more conveniently in small quantity by pouring hydrochloric acid upon black oxide of manganese in a retort, and applying a gentle heat as before. In this case, a portion of the acid is decomposed, and the element chlorine passes off in the form of a green pungent gas.

Chlorine enters into numerous highly important and interesting combinations; but we must turn from them in the meantime, to indicate the leading features of the allied elementary body

Iodine.—This element is obtained chiefly from sea-weeds, but was discovered accidentally in 1812, by M. Courtois in the mother-waters of his saltpetre works, and it has since been found in combination with potassium and sodium, in many mineral waters, such as the brine spring of Ashby-de-la-Zouch. Kelp contains it abundantly, as do also the mother-waters of the salt works upon the Mediterranean Sea; and it has been recently found in combination with silver in some ores brought from the neighbourhood of Mexico.

Iodine may be procured by drying and powdering common sea-weed—sponge for instance—and heating it with sulphuric acid; a *violet* vapour rises, which if received in a cool vessel, will condense on its sides, and form scaly crystals of a somewhat metallic lustre. These crystals are the substance in question; and it is named from the violet colour of the vapour. It is most economically procured however from the mother-water of kelp, as furnished by the soap manufacturers, who employ that crude alkali. The water is mixed with an excess of sulphuric acid in a retort, and exposed to heat, when the violet vapours of iodine distil over, and may be condensed as already described.

Iodine is always solid at atmospheric temperatures, but it slowly volatilizes, emitting a peculiar offensive penetrating odour, somewhat like chlorine. It fuses at 220°, and boils off rapidly at 350°. It enters into many combinations: two of them, the iodides of potassium and iron, are used in medicine, and another, the per-iodide of mercury, is a brilliant red pigment, but somewhat evanescent. But the chief use to which iodine has as yet been put in the arts, is the detection of a starch, with the watery solutions of which it forms a compound of a deep purplish blue colour.

Bromine.—If a large quantity of sea-water be boiled down, and the common salt removed until no more freely crystallizes, we obtain a residual liquor, which salt manufacturers call *bittern.* An abundance of it can be procured at salt-works, where it is often thrown away as useless. It contains in solution a salt of exactly analogous constitution to the chloride of sodium, but in which another non-metallic element is in combination with the sodium. It may be separated by passing chlorine gas through the liquor, which, from a superior affinity, combines with the metal, and a deep brownish yellow colour is immediately developed, and a peculiarly strong and disagreeable odour. The liquor being then heated in a retort, red vapours will pass over, and fill the receiver, and, with proper means, a few drops of a volatile liquid of a hyacinth red colour may be obtained: these are *bromine.*

At ordinary atmospheric temperatures bromine is a liquid; a little below 0° it congeals and is very brittle, and it boils at $116\frac{1}{2}$°. It is poisonous. Applied to the skin it colours it deep yellow, and corrodes it. It is soluble in water, alcohol, and particularly in ether: with water it forms a crystalline combination at 32°; the crystals are octohedrons, of a red tint, and continue permanent, even at the temperature of 50°. It produces a deep orange yellow colour when mixed even in small quantities with cold solutions of starch. It combines with silver, forming with it an insoluble *bromide,* which, being in contact with organic matter, is quickly blackened by exposure to solar light. On account of this property, bromine is highly valuable in photography. Thus, if a sheet of paper be washed with a very dilute solution of the bromide of potassium, and then with a solution of nitrate of silver, the salts are decomposed, and bromide of silver is formed in the substance of the paper. The paper remains white if kept in a dark place, but is immediately blackened by exposure even to diffuse daylight. It is decidedly the most sensitive of the photographic papers.

Fluorine.—This is the name of an elementary body which has not hitherto been obtained, at least in satisfactory quantities, in a separate state. The assumption of its separate existence may therefore be considered as somewhat hypothetical, although supported by the strongest analogies. Its powers of combination are supposed to be so exalted, that no body has been found capable of subverting its affinity. Provisionally, a name has been given to it. It is met with as a component of a few minerals, but the only one of these found in abundance is *fluor* spar, otherwise called Derbyshire spar, and which, analogically, we regard as a *fluoride of calcium*—that is a compound of fluorine and calcium, the metallic base of lime.

## ANATOMY AND PHYSIOLOGY.

### CHAPTER XV.

respiration.—(*Continued.*)

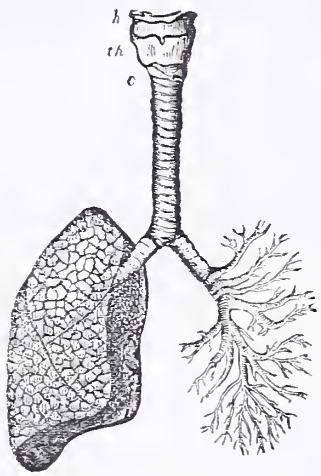
It has been already stated, that when the blood has got into the veins, and arrived at the right side of the heart, it has lost its bright red colour, and has become purple, or almost black; it has ceased to be arterial, and has become venous. The cause of this dark colour is the quantity of charcoal or carbon which it has received in its passage through the intimate

* This is, in some chemical works, still called *muriatic acid,* a name borrowed from the old one of *marine acid,* which, for popular use, was translated into *spirit of salt.* These names, as we shall see, are not inappropriate, the great source of chlorine being the salt of the ocean; but the name given in the text, and which is now very generally adopted by chemists, is better, in as far as it indicates the composition of the acid.

structure of the different organs. It has also parted with the oxygen or vital air which it held in combination. Now this black blood is calculated to produce death in two ways: first, it deprives the muscles of their power of contraction, and consequently stops the heart, which is a muscle; and secondly, it destroys entirely the action of the brain. The manner in which it produces death will be fully detailed in the article on that subject, under the head of 'Asphyxia.'

Respiration, then, is a contrivance by which the blood is brought into contact with the air, so as to permit these two fluids to effect chemical changes upon one another; and here we have to examine the structure of the lungs and the chest.

Each lung may be compared to a bunch of grapes: it consists of an infinite number of little cells, each not larger than

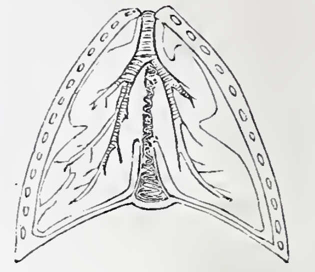



a millet seed, fixed upon footstalks; each footstalk being a tube, a branch of the windpipe. When the air comes in through the windpipe, then all these air-cells become filled; and this is done by the heaving of the chest, which is called *inspiration*. When again the chest falls, the air-cells are partially emptied, but never completely, and the air which was in them is blown out by the windpipe: this is called *expiration*.

The *windpipe* is a tube, consisting of eighteen or twenty cartilaginous rings, united by an elastic membrane; it is connected to the back of the mouth, where the air enters it; it passes down the front of the neck, enters the upper orifice of the chest behind the top of the breastbone, and divides into two branches, one for the right lung, and one for the left. In the lung, the windpipe subdivides into a great multitude of branches, and these into little twigs, on which the air-cells are hung—it has already been said—like grapes upon their footstalks. These tubes and air-cells are lined with a delicate membrane, called *mucous*, on account of the mucus which moistens it; and their coats become exceedingly thin, so that the air within them, and the blood without, can exercise a chemical influence on one another through them. The *pulmonary artery*, which brings the dark blood from the right side of the heart, divides into two branches, one for each lung, and each branch subdivides into minute ramifications, which spread themselves over and between the air-cells. The *pulmonary veins* take their commencement from the arterial capillaries on the surface of the cells, and unite with one another till two large ones are formed from each lung, which convey the red purified blood into the left auricle.

The vesicles have been described as being fixed to the air-tubes, in the same manner as a bunch of grapes are fixed to the footstalk; but here the similarity ends; for the cells are so small, and so close together, that no interstices between them can be perceived. Indeed, on looking at the surface of a lung, it seems to consist of an infinity of shining points, which, on being examined more closely, are found to be the cells filled with air. After air has once got into the lungs, it can never be completely expelled: hence, the lungs of a person who has breathed always float in water; and on this fact is founded the test used in criminal examinations, to distinguish a stillborn child from one that has breathed, where there is a suspicion of child-murder.

In the accompanying figure, the front of the chest is represented as cut off, so as to show the lungs without it. The windpipe is seen descending and dividing into its two branches, which are entering into the lungs; but the branches of the arteries and veins are omitted, because they would have made the small figure too complicated. Each lung is of a conical form—its base below, and its apex above—its base rests on the upper surface of the diaphragm; its apex reaches up into the root of the neck; its back touches the spine; and its front and outer parts are covered by the ribs. Towards the middle, the lungs are not in contact, being there separated



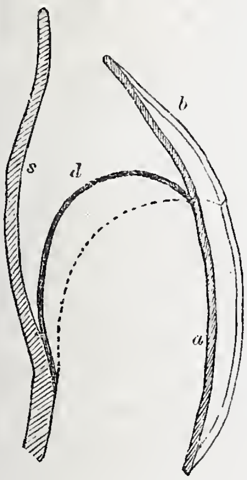
by the space in which the heart lies. Each lung is divided by fissures into lobes, of which the right lung has three, and the left only two; the place of the middle lobe being occupied by the heart, which, it has already been stated, though in the middle, encroaches upon the left side. The whole lung, except the part where the windpipe and blood-vessels enter it, is covered by a thin smooth membrane called the *pleura*, which is represented in the last figure. It is a shut sac, having one layer investing the lung, and the other lining the walls of the chest, the walls of which are in contact, so that it forms a close bag; though in the drawing, for the sake of plainness, a space is represented between them. The pleura is moistened with a thin serous fluid, similar to that in the pericardium, which enables the lung and chest to glide upon one another in the action of breathing. This membrane is very liable to become inflamed, causing acute pain, and constituting the disease called *pleurisy*. Sometimes a quantity of water is poured out into the cavity of the pleura, when the absorbent vessels do not take up what the arteries have poured out, and dropsy of the chest is the consequence. Sometimes after a chronic inflammation of the pleura, matter is formed, which presses on the lung, preventing it from performing its functions, and requiring to be let out by an incision made in the chest, between the sixth and seventh ribs.

When a child is born, its lungs are empty, and the sides of the chest are as much compressed as they can well be. Whenever it has got into the air, the elasticity of the ribs causes its chest to enlarge—the outer surface of the lung being in contact with the chest, accompanies it, and so a tendency to the formation of a vacuum is caused. The air now rushes down the windpipe, into what would otherwise be empty space, and thus the first inspiration is made, and when once made, it is repeated eighteen or twenty times per minute, during the whole course of our existence.

The vacuum produced at first by the elasticity of the ribs can never be repeated,—the lungs never become emptied of the air that now fills them, but after a forced expiration, they are at their most empty state, and they can be filled again to the utmost by an exertion of muscular power. Over each side of the chest spreads a great muscle, which may be likened to a hand with outstretched fingers, laid on the chest, the fingers pointing downward and forward—only, instead of five fingers, it has nine *indigitations*. Each of these indigitations is attached to one of the nine upper ribs, and the back part of the muscle is fixed to the posterior edge of the shoulderblade. It is not seen sufficiently well in the plate of the muscles in Vol. I. for me to refer to it. From the direction in which the ribs are curved, first outward, then downward and forward, any force acting on them from above

and behind, pulls them upward and outward, and so increases the capacity of the chest. The muscle which has just been spoken of does so constantly; but there are others which do so only occasionally, such as those which run from the chest to the bone of the arm. An asthmatic person may be seen, when the fit is on him, holding by the arms of his chair, to make them fixed points for these muscles to act from upon the chest; and he holds up his head to make these muscles of the neck co-operate in inspiration, which are attached to the collar-bone, and to the upper rib.

But the principal muscle of inspiration is one which has been spoken of already more than once, as separating the cavities of the chest and the abdomen. It forms an arched floor to the chest, having its edges attached to the ribs and to the breast-bone at the sides and in front, and to the spine behind. It is represented in the figure on the margin by the arched line *d*, as in a state of rest. It is also seen in the preceding figure arching across. When it contracts, it necessarily tends to become straighter, like the dotted line—it therefore increases the capacity of the chest; the lower parts of the lungs descend with it, while the upper parts rise with the ribs and breast-bone *b*, which comes into the position indicated by its corresponding dotted line; and thus the chest is enlarged, both upward, and outward, and downward, at once. As the diaphragm descends, it pushes the contents of the belly before it, so that, at the moment when the breath is drawn in, the belly becomes more prominent. At this time the abdominal muscles *a*, closing the belly in front and at the sides, are relaxed. When the diaphragm and elevators of the ribs cease to act, the chest falls, the abdominal muscles press the bowels up against the hollow of the diaphragm, and push it into the chest; the capacity of the chest is thus lessened in every direction, and the air which had been drawn in is again blown out, or expired.




Inspiration and expiration, then, are two different actions which are constantly going on, from the moment of birth to that of dissolution. In different persons, the frequency of respiration varies, in some being as low as 16, and in some as high as 24 in the minute. In the infant it runs as high as 40. It frequently varies with the degree of rest or activity, and with the frequency of the circulation with which it is limited, in an indissoluble sympathy. When a person is lying quiet in bed, it has already been stated that the pulse is four or five beats slower than when erect, and the respiration is slow in proportion. When again, by exercise, or even by mental emotion, the action of the heart is quickened; the breathing becomes more frequent, keeping in the ratio of 1 to 4; that is to say, that during one act of inspiration and expiration, the heart will contract four times.

Three different degrees may be observed in respiration:—First, there is the gentle equable motion which goes on when we are at rest, or when asleep, when the diaphragm and the small muscles between the ribs (see plates of muscles) are the agents which are quietly drawing in the air. Secondly, we have an increase of action when the great serrated muscles are brought in aid of the intercostals to lift the ribs, as when excited by exercise; and thirdly, we have the forced acts of inspiration, when, by a strong exertion of the will, we draw in the air to the utmost, as in asthma, or in preparation for any strong muscular exertion. The first of these is involuntary, and goes on whether we are awake or asleep; the second is also involuntary, and may be called a state of *excited* respiration. The third is the state of *forced* inspiration, when several muscles, which are not ordinarily muscles of inspiration, become so under the influence of the will.

The lungs of a man are estimated to contain about 330 cubic inches of atmospheric air, when filled as full as they can hold, by drawing in the breath to the utmost. At each act of respiration we draw in and expel about 40 cubic inches, so that when the lungs are at rest, after an ordinary expiration, they contain about 290 cubic inches. Now 40 is very nearly one-eighth of 330, so that about one eighth of the air in the lungs is renewed at each act of respiration. Besides the 40 cubic inches expelled in ordinary expiration, we can, by an act of the will, blow out 170 cubic inches in addition, making the whole quantity expired amount to 210 cubic inches. This still leaves 120 cubic inches in the lungs, which therefore never collapse, but always float in water, as mentioned near the commencement of the chapter

From what has been stated it will at once be known how necessary it is that all houses and rooms should be so built as to contain a sufficient supply of air for the use of the inmates; that there should always be some means of renewing the air, as by the current produced by a fire in an open grate; and that, if stoves or heated air-pipes be used for distributing heat, there must be, at the same time, a set of ventilating pipes, otherwise the apartments will speedily become unwholesome, and their atmosphere incapable of supporting life. If an individual make 20 respirations in a minute, he will consume 800 cubic inches of air in that time, 48,000 in an hour, and in a day of 24 hours, the enormous quantity of 1,152,000 cubic inches. The importance of these calculations, so long neglected, is now fully admitted; and in the present day, no architect makes plans for churches, hospitals, or barracks, without calculating the height, width, and cubic contents, with reference to the breathing of the numbers that are to occupy them. Too little attention is paid to this, however, in building our ordinary bed rooms—nearly the whole space in the house is devoted to handsome public rooms, while those in which a third of our time is to be spent, are so small that the air in them is soon exhausted, and in the morning, (as is obvious to any one entering them from the open air,) they are positively unwholesome.

An account of the chemistry of respiration will be given at length in the following chapter.

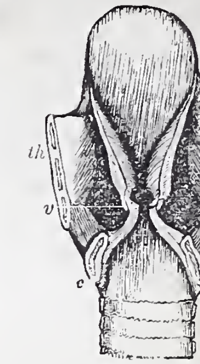
The whole of the air-passages are lined with a delicate mucous membrane, which is kept constantly moist with a thin mucous secretion. After exposure to cold, this secretion becomes increased in quantity, accumulates in the air-tubes, and excites a desire to spit it up—accomplished by coughing, which is just a short, quick, somewhat convulsive expiration. A feeling of heat is generally experienced all through the lungs from the inflammation of the membrane. This complaint generally soon goes off, by the use of warm drinks, and attention to clothing. As the inflammation subsides, the secretion becomes thicker, and is spit up in firmer dark-coloured globules. When the inflammation spreads to the substance of the lungs, the case is much more serious; the patient has a dull uneasy feeling in the lung, but not a sharp pain as in pleurisy, (which we described near the commencement of this article;) he spits up matter tinged with blood, and if the disease be not checked, such an impediment is put to the purification of the blood, that death necessarily ensues. This disease requires the most active treatment—free bleeding, several times repeated, besides the use of internal medicines, and the application of blisters, which, by exciting inflammation of the skin, cause a revulsion which lessens the inflammation of the parts within.

The most dreadful complaint to which the lungs are subject, is that which is known by the name of pulmonary consumption. In this disease the upper parts of the lungs become filled with little round grayish bodies called *tubercles*, which soon render these parts impervious to air, and so produce cough, and difficulty of breathing. After having existed in this state for some time they soften, and are spit up through the branches of the windpipe, leaving excavations of greater

or less extent. The patient, after a longer or shorter time, dies, exhausted from irritation, or, sometimes, is cut off suddenly by one of the blood vessels of the lung bursting into the cavity. Till within the last twenty years no way was known of ascertaining the existence of this sad malady, until it had gone such a length that its external signs could not be mistaken; but now, like all the other affections of the lungs, it can be readily detected by a practised ear, with the aid of the *stethoscope*, an instrument which was already spoken of in Chapter XIII. By its aid we hear the air rushing into the air-cells, and can detect the various unnatural sounds which are the consequences of various unhealthy states of the lung. Indeed, by merely laying the ear upon the naked chest the breathing can be plainly heard. But to return; even when we have ascertained the existence of consumption, we cannot apply the old adage, that the knowledge of a disease is half its cure; for this intractable complaint, when once really commenced, never has been, and we may rest assured, never can be cured.

The *windpipe* separates from the gullet behind the root of the tongue, and lies in front of it in its course down the neck. Besides its principal use of admitting air to the lungs, it has another, very important too, though a secondary one, the office of producing the voice. The vocal apparatus is placed near the top of the windpipe; it is called, in anatomy, the *larynx*, from the Greek word signifying a musical pipe made of a reed, and there is no English word which corresponds to it. The larynx, besides, has two offices,—its principal one being to produce voice; and another, of no less utility, is to prevent food from getting into the windpipe in its passage from the back of the tongue into the gullet.

The framework of the larynx consists of one bone and four cartilages. The bone is not preserved in general as a part of the skeleton, for it is not united to any other bone, but is situated in the root of the tongue. It has a convex border turned forward, to which the muscles are inserted that draw the tongue forward, and protrude it from the mouth. It has two horns that pass backward, and serve like tenterhooks to keep the bag of the gullet open at the back of the tongue. The *thyroid* or protecting cartilage is below this,—it also is convex in front, and concave behind; it has a notch in its upper border, and is felt on the front of the neck, and seen prominent in the male, whence its common name of *pomum Adami*, as if the forbidden apple had stuck there. Below the thyroid cartilage is another called the *cricoid*, from the Greek word signifying a ring; for it completely encircles the windpipe. These parts are marked *h*, *th*, and *c*, in the figure of the lungs. That part of the windpipe which has been spoken of some pages back, as composed of cartilaginous rings, is attached to the lower edge of this. Placed above the cricoid, and within the thyroid, are two small conical cartilages, to which the *vocal chords* are attached. These chords are fixed in front to the hollow or indented angle of the thyroid cartilage, and are joined behind to the two conical ones, so that a slit is formed between them, which regulates the admission of air. Eleven small muscles move the several parts of the skeleton of the larynx upon one another, drawing its several parts in different directions upon one another, and opening or closing the slit or chink of the windpipe. This chink may be lengthened and widened, or lengthened and narrowed, shortened and widened, or shortened and narrowed to imperceptible degrees; thereby varying, with infinite minuteness, the musical notes which are elicited by the air passing through them. This figure represents the larynx, with a slice cut off its back part; *th* is the thyroid: *c* the cricoid; and below are three of the rings. The vocal chords *v* are seen cut across at the narrowest part. The vocal chords do not vibrate after the manner of strings, as some have supposed, who have taken great pains to prove that the larynx is at once a wind and a stringed instrument; it is purely a wind instrument, whose notes are produced in a similar way to those of the reed in a clarionet or hautboy. In the clarionet, the reed is always the same, and the different notes are produced by lengthening or shortening the sounding tube, by stopping or opening the holes with the fingers. In the larynx, the reed is continually being changed by the variations in the vocal chords, while the length of the pipe is also varied by the elevation and depression of the larynx, through the means of the muscles which attach it to the chin above, and to the breast-bone beneath. This motion is easily felt, if the finger be laid on the fore part of the neck while singing: in running up the scale, the projecting cartilage is felt rising a step for every note; and, towards the top, additional elevating power is gained by holding up the head, and pushing out the chin.




The chink between the vocal chords is not, at the utmost, more than three quarters of an inch in length, and varies in width from a quarter of an inch to absolute closure. Hence it must be obvious, that a small substance getting in will block it up altogether, and that thickening of the chords from inflammation may narrow it so much as to produce death by suffocation. This is what takes place in fatal cases of croup: layers of a firm whitish substance, of the consistence of boiled white of egg, are formed in the interior of the windpipe, which narrow it, and prevent the free ingress of air; and, if relief be not obtained from the most active medical treatment, death will speedily ensue. The narrowing of the chink gives rise to the convulsive cough, and the peculiar ringing sound of the respiration, which are characteristic of the disease.

As soon as food reaches the back of the throat, it passes from the power of the voluntary to that of the involuntary muscles, and is conveyed into the stomach by a regular wave-like action of the muscular gullet or œsophagus. When persons eat too fast, and one morsel is passed into the throat too quickly after the other, this regular muscular action becomes spasmodic, producing a very painful sensation.

Where foreign bodies get *into* the windpipe, their presence there is a proof that they cannot produce death by suffocation; because the chink is the narrowest part of the tube, and they have passed that. They are, however, driven up and down by the successive currents of air, and produce much irritation, and at length death from inflammation of the lungs, if not extracted. The operation for removing them is a very simple one; an incision is made on the front of the neck down to the windpipe, which is then slit up for near an inch. No poking with instruments is required, for the moment the opening is made, the foreign body is blown out with great force. A cherry or plum stone is the substance which, in most cases, has got into this awkward situation.

In order to prevent food or drink from passing i to the windpipe while being swallowed, a valve is placed over the orifice of the larynx. This valve is called the *epiglottis*. It is shaped like an obovate leaf, fixed by its footstalk to the inside of the angle of the thyroid cartilage, while its broader part can be laid down over the orifice so as completely to close it. It stands erect in its natural position; it has no muscle to pull it down, but is pushed down mechanically by the ball of food which passes over it from the root of the tongue to get into the gullet, and the moment this has passed it again rises by its elasticity. Indeed, food can never get into the windpipe but when this part is taken by surprise, either by speaking or laughing while swallowing, or by swallowing in a hurry as a child does when in fear of detection in having stolen some sweet thing.

The only complaints about the larynx, occurring in adults are an affection somewhat resembling the croup of children, and an ulceration in the inside, reaching even to the cartilages, which is occasionally found in persons perishing from consumption.

# THEORY AND PRACTICE OF DYEING.

## CHAPTER V.

### BLEACHING.

We have already had occasion to notice the necessity of goods being a pure white previous to being dyed any light *fancy** shade; otherwise the natural yellow colour of the goods, whether cotton, silk, or woollen, would interfere with the particular shade wanted. If, for example, the shade required be a light pink upon cotton, and a little safflower—the stuff used for dyeing pink, and which will be described by and by—be put upon it unbleached, the resulting colour would not be a pink, but a shade intermediate between a salmon and a brick colour, from the yellow ray reflected from the cotton mixing with the red reflected from the dye. We must, therefore, before dyeing a light pink, get rid of these yellow rays, and this is obtained by the process of bleaching. Hence, the dyer must, of necessity, be also a bleacher, and one, too, who has more to attend to than merely producing a good white; for as the substances used for bleaching are in general hurtful to the fancy colours, he must be very careful that the one process shall not interfere with the other.

These remarks, we think, will satisfy the reader of the necessity of giving an outline of the process of bleaching, previous to describing the nature of the stuffs and processes for dyeing those colours which require to be dyed upon bleached goods. The colours we have already described; namely, black, vat blue, and green, do not require bleaching except for some particular light clear shades of the two latter.

Where and when the practice of bleaching cloth first began to be practised we have no account; but we may reasonably suppose that, as soon as man became so far civilized as to manufacture clothing, that the constant exposure of that clothing to the atmosphere, and occasional washing, would naturally suggest the idea of bleaching. However, we know that bleaching is of very ancient origin, mention being made of it in the oldest books extant. What was the nature of the process practised in these early times, is not clear; but from the earliest description to the close of last century no other process was known but alternate boiling, washing, and exposure to the atmosphere—a process which required a number of months to complete; but, since the application of chlorine to this purpose—an application which as Graham observes, "is one of the most valuable which chemistry has presented to the arts"—the process is completed in a few days; nay, for the most of dyeing operations, in a few hours.

As many are now unacquainted with the routine of the process of bleaching previous to the introduction of chlorine, it may be worth while to give a short description of it, to illustrate the advantages obtained from the application of science to the arts. The first operation was that of steeping, which was merely immersing the yarn in hot water or cold alkaline leys. When water was used the steeping lasted for three or four days, but with alkaline leys forty-eight hours were sufficient; the goods were then washed, and boiled in an alkaline ley for four or five hours, washed and exposed on the grass for two or three weeks, again boiled or bucked, which is a technical term for boiling; washed and crofted, a technical term for exposing on the grass, as before. These alternate operations of bucking, washing, and crofting, were generally repeated four or five times, each time reducing the strength of the alkaline leys in which the bucking was performed.

The next process was that of souring, which, till nearly the middle of last century, consisted in steeping the goods for several weeks in soured butter-milk. This process was much shortened by Dr Home, who suggested the use of sulphuric acid (vitriol) instead of milk; and twelve hours, with a sour of this acid, were sufficient.† After the first souring, the operations of boiling, washing, souring, and crofting, were repeated in regular rotation, until the yarn came to a good colour, and was esteemed perfectly clear. A quantity of soap was generally used in the last operations of boiling. The number of times these operations were repeated varied according to the quality of the goods; linen was seldom finished in less than six months; cotton goods varied from six weeks to three months.

Various opinions were advanced to explain the nature of the chemical changes induced during these operations; but such opinions could only be hypothetical so long as the composition of the atmosphere and of water were not known—two substances which acted a very prominent part in these operations. And neither can we offer any explanation till once we are acquainted not only with the composition of the atmosphere and water, but also of the colouring matter upon the goods. Pure water is composed of oxygen and hydrogen in the proportions by weight of eight of the former to one of the latter. The atmosphere is composed in the 100 parts by weight of 79 nitrogen, 20 oxygen; the remaining one being carbonic acid gas and watery vapour. The composition of the colouring matter of the goods has not as yet been very accurately ascertained; but, from several experiments made upon it, its properties are neutral, and will, therefore, from the rule laid down in the first Chapter, be composed of equal portions of oxygen and hydrogen united to carbon; but, besides this colouring matter, there is also a resinous substance upon cotton which resists the action of water and makes it very difficult to moisten, (*wet out*). This resinous substance is composed of hydrogen and carbon, and is soluble in alkalis and water, and is therefore mostly all taken out by steeping and boiling. These resinous and colouring matters do not form a part of the cotton, but mechanically adhere to it, so that substances may act upon and decompose them without in the least destroying the cotton; indeed, from a number of experiments, cotton is found as strong when deprived of these substances as before.

In order to ascertain the chemical changes which take place when goods are bleached in the air, Mons. Berthollet—finding that those seasons when most dew was deposited, were the most effective upon the colour—examined the dew which falls from the atmosphere, and also that which transpires from the grass, and found both to contain a sufficient quantity of oxygen to destroy the colour of turnsole paper.‡ What errors led to these results we do not know, for although dew did contain oxygen it would not give it acid properties to redden turnsole paper. Or, whether M. Berthollet considered the bleaching property of dew due to its having free oxygen, or to this acid property, we do not know, not having seen the original details. The theory of croft bleaching has been explained variously as follows:—

1. The oxygen of the atmosphere combines with the colouring matter of the cotton forming a new substance capable of solution in water or alkalis, and comes off by washing or boiling; or it combines with some of the elements of the colouring matter, such as the carbon forming carbonic acid gas, which escapes into the air, or with the hydrogen and forms water; those elements which are left, form either colourless substances, or substances soluble, in the next operation.

2. The oxygen combines directly with the colouring matter forming a permanent and colourless oxide.

3. That water acts otherwise than being merely a solvent; that it or one of its elements combines with the colouring substance producing the effects noticed in the first proposition. Hence, dew being pure and free from any admixture which might retard this union, is better fitted for bleaching; consequently, the seasons when most dew is deposited, the bleaching process will be accelerated. Which of these theories is the true one we cannot say; but, from observation, light facilitates the process of bleaching, and this circumstance, we think, favours the supposition of the colouring matter being decomposed. Other interesting theories might be advanced from phenomena observed during the process of croft bleaching; and also the part the alkaline boils, and the sours take in the operation, but our space will not permit us to enter into details.

The modern process of bleaching, and that which is now almost universally practised, is by means of chlorine. This substance was discovered in the year 1774, by Scheele, who also described its peculiar property of destroying vegetable colouring matters; but M. Berthollet was the first who called the attention of the public to its value as a bleaching agent in 1785. About the time this chemist was prosecuting his inquiries into the nature of this substance, he was visited by the celebrated

* This is a technical term for fugitive colours, or colours not fast.

† Home on Bleaching.

‡ Park's Chemical Essays.

James Watt, to whom Berthollet related the results of his experiments upon bleaching, and by this circumstance the inventor of the modern steam-engine became also the introducer of the new process of bleaching into this country.*

The introduction of chlorine as a bleaching agent, like all other discoveries which tend to overturn old practices, met with a host of oppositions. The most prominent objections offered were, that it destroyed the cloth—did not give a permanent white —and it killed the men who wrought with it. These oppositions were not altogether groundless, but the force with which they were urged hastened the improvements and effected remedies. The first method of using chlorine was by saturating cold water with the gas,—the water taking up about twice its volume of it. The goods were put in this water, after which it was heated to drive off the chlorine, or set it free, that it might act upon the colouring matter ; but, the goods being impaired by this process, even when the greatest care was taken, suggested the diluting of the chlorine water; which diluted liquor was found to bleach equally well, and the goods were preserved. The defect of the goods becoming yellow after a few days suggested alternate boiling with alkaline leys ; and the difficulty arising from the workmen being unable to endure the effects of the escaping gas, led to the discovery that alkalis not only absorb a greater quantity of chlorine than water, but that they hold it with greater affinity, not allowing the gas to escape and affect the atmosphere, at the same time parting with it more regularly and effectively to the goods. The alkalis used were soda and potash, and each bleaching work had its regular apparatus of retorts and carboys, or wooden chests, for the purpose of making their own chloride of potash or soda. This practice is still continued in many print works, both in Scotland and England, for particular fabrics or delicate operations, as it is considered much safer and better adapted for certain purposes than the common bleaching powder. In the year 1798, Mr Tennant, of Glasgow, patented a process for using a solution of lime for absorbing the chlorine instead of potash and soda ; shortly after, the hydrate of lime (slaked lime,) was substituted for lime water, and this is the preparation now used for bleaching, under the names of bleaching-powder and chloride of lime. Other minor improvements have been made regarding the quantity of chlorine absorbed by the lime under certain conditions which will be noticed afterwards.

Notwithstanding all these discoveries and applications, the real nature of the decolouring agent was still unknown ; it was prepared by digesting together a mixture of common salt, peroxide of manganese, and sulphuric acid ; a decomposition took place which was explained as follows :—The sulphuric acid combined with the soda of the salt and set the muriatic acid, which was in union with the soda, at liberty. The oxide of manganese gave off a part of its oxygen which combined with the free muriatic acid, and formed oxygenated muriatic acid—a name which was first applied to this new substance; but after being introduced into the arts this name was considered too unwieldy for common use, and was therefore contracted into *oxy-muriatic acid.* It was ultimately contracted, by the workmen, into *oxygen*, and, notwithstanding the discovery of Sir H. Davy in 1811, that oxy-muriatic acid was not common muriatic acid with more oxygen, but a simple body which he called chlorine—the name oxygen is still given to bleaching powder, and all its preparations. We need scarcely tell the reader that this is erroneous, in so far as oxygen is the name of another element differing widely from chlorine both in its nature and properties. It is also a great evil to the workmen themselves, by incorporating in their minds the properties of one substance with those of another. We still remember the difficulty we were in when hearing that it was the oxygen of the air that supported life, and that it was the same oxygen which turned the green colour of the goods while in the vat to blue when exposed to the atmosphere, and at the same time, seeing bleaching liquor, which was also termed oxygen, destroying blues, and felt that we could not breathe its gas but with the greatest difficulty. To solve this puzzle, every chemical book we could find was examined for remarks on oxygen ; but, to our mortification, not one of these remarks alluded to its bleaching properties. We doubt not but many others have been in the same dilemma. The following order will show our chemical friends the ridiculous position dyers and bleachers place themselves in by retaining such names.

Glasgow, ———, 1852.

"Messrs * * Will please send, at their earliest convenience, a cask of their strongest oxygen, containing as near as possible 2 cwt.; let it be newly made and dry, the last was damp, so that in a few days it became like as much clay, and lost the most of its strength."—Your attention will oblige,

Yours, &c., &c.

We have been informed by a respectable calico printer that *chemic* is a common name for bleaching liquor in many print works; and we know that there are many more erroneous names for other substances. We will, probably, give a table of these technical terms with their proper equivalents. In the mean time we state that there is no better name for the substances we have been describing than *bleaching powder*, or, if in solution, *bleaching liquor.*

It is sufficiently well known that the method of making bleaching powder is to expose the hydrate of lime (slaked lime) in fine powder to an atmosphere of chlorine, till the lime ceases to absorb more of the gas. When the lime is in combination with an extra atom of water it will absorb much more chlorine than when it has just as much water as slake it. The chlorine is passed into large vessels or chambers furnished with shelves, upon which is placed the lime. Bleaching powder is white and pulverulent ; it has a hot, bitter, and astringent taste, and a peculiar smell. When digested in water it leaves behind carbonate of lime, and some other impurities.

Some of the continental chemists first suggested that the chlorine was not merely absorbed and retained by the lime, but that it combined with it and formed one or more definite compounds. This has led to a great deal of research, but scarcely any definite conclusions—there being various compounds of chlorine with oxygen which may be formed during the preparation of bleaching powder, and which possess bleaching properties as well as the chlorine alone ; but the details of these researches do not come within our limits. Whoever feels interested in them, will find a series of papers upon the subject in the 2d volume of "the General Records of Science," by Balard.

The best bleaching powder of commerce seldom contains above thirty per cent. of chlorine available in bleaching ; but there are few substances which the dyer or bleacher have, more liable to change ; indeed, from its first formation, there seems to be a constant chemical action going on between the chlorine and the lime ; oxygen is disengaged, and chloride of calcium is formed—a substance which possesses no bleaching properties. These changes may be much retarded by keeping the powder perfectly dry, or by dissolving it in cold water, and keeping the solution excluded from the air. Chloride of lime (bleaching powder) does not attract moisture from the atmosphere as is supposed by dyers, but when exposed to the atmosphere, it is changed more rapidly into the chloride of calcium, a substance that is very deliquescent, and allowing that the lime previously contained two atoms of water, which combining with the chloride of calcium, when formed, places this salt in the best circumstances for attracting more water from the air, thus hastening the destruction of the remaining chloride of lime. We have seen good bleaching powder by a little inattention, reduced to this state in a few weeks, and its bleaching properties almost totally destroyed.

As chloride of lime loses its bleaching properties by standing, and several other circumstances, it is of the utmost consequence to the consumer, that he have some means of determining its real value, both for the sake of safety and accuracy in his processes, and its commercial worth. We have seen casks of bleaching powder which did not contain above ten per cent. of chlorine, charged and paid for at the same rate as that which contained thirty per cent. ; but not having the means of testing it previously, the quality was not discovered till the salt was in solution ; indeed we are not aware of any relative prices according to the quality of this article, although with a very little care and trifling expense, the dyer may know the value of the article he is about to purchase, and of course only pay accordingly. The first method of determining the value of bleaching powder was by sulphate of indigo, but the indigo solution alters by keeping, and is therefore objectionable. "Several

* Some give this honour to Professor Copland of Aberdeen; but, from the evidence we have seen, it belongs to Watt, although the difference of time was little.

exact methods," says Graham in his Elements of Chemistry, "of which that in which sulphate of iron is used, appears to be entitled to preference. This method reposes upon the circumstance that the chlorine of chloride of lime converts a salt of the protoxide into a salt of the peroxide of iron. It is found by experience that ten grains of chlorine are capable of peroxidizing 78 grains of crystallized sulphate of iron. In an experiment to determine the per centage of chlorine in a sample of bleaching powder, some good crystals of protosulphate of iron (copperas) are to be pounded and dried by pressing between folds of cloth ; 78 grains are dissolved in about two ounces of water acidulated by a few drops either of sulphuric acid or muriatic acid ; then 50 grains of the chloride of lime to be examined, are dissolved in about two ounces of water, by rubbing them together in a mortar, and the whole poured into a vessel graduated into a hundred parts. The common alkalimeter will do. This is a straight glass tube, or generally a very narrow jar about $\frac{5}{8}$ths of an inch in width, and 14 inches high, mounted upon a foot, as shown in the accompanying figure, capable at least of containing a thousand grains of water, and graduated into a hundred parts. The jar containing the 50 grains of chloride of lime is filled up to the highest graduation by the addition of water, and the whole is well mixed. The clear of this solution is gradually poured into the solution of sulphate of iron till the latter is completely peroxidized. This is known by means of red prussiate of potash, which gives a blue precipitate with the protoxide, but not with the peroxide of iron. A white plate is spotted over with small drops of the prussiate ; a drop of iron solution is mixed with one of these after every addition of chloride of lime ; and the additions continued so long as the prussiate drops are coloured blue.

They may be coloured green, but that is of no moment. When the iron is peroxidized, the number of graduations or measures of chloride of lime required to produce that effect is noted ; the quantity of chlorine in the 50 grains of bleaching powder is now known, being ascertained by proportion. Thus, if it required 68 measures of the bleaching solution, then as 68 is to 10, so 100 is to 14·7, the chlorine in the 50 grains of powder ; this being multiplied by two gives the per centage of chlorine in the sample, which is 29·4."

Another process has been recommended by Gay Lussac, which combines simplicity with accuracy, and is coming into general use with the manufacturers of bleaching powder. A solution of arsenious acid is made in muriatic acid, and diluted with water. On adding a solution of chloride of lime, the muriatic acid takes the lime ; the chlorine decomposes the water, combining with its hydrogen, while the oxygen unites with the arsenious acid, and converts it into arsenic acid. When the arsenious solution is tinged with sulphate of indigo, and bleaching liquor added, there is no change takes place on the indigo until the whole arsenious acid is transformed into arsenic acid ; but the first drop after this discolours the indigo. The correctness of this test is founded upon the knowledge of what proportion of chlorine is necessary to oxidize the arsenious acid in the test solution. Various proportions have been proposed as the standard strength of the solution, but it does not matter much what proportions are used provided the operator knows what proportion of chlorine is necessary to transform it, and being careful always to have it the same. The best proportions for general use are those that require the least calculation. The following proportions we have found to do very well, and to be easily counted. Take one ounce of arsenious acid (common arsenic of the shops), and dissolve it by digestion for a few minutes at a boiling heat, in 24 ounces by measure of pure muriatic acid, then add 46 ounces by measure of distilled water; but in case of any loss by evaporation during digestion, it is better to have a vessel which contains up to a certain mark 70 ounces, and when the acid solution is put into it, to fill up to the mark with water. This may be bottled and put past as the standard test liquor. Every three ounces by measure of it are equivalent to twenty-five grains of chlorine. When a sample of bleaching-powder is to be tried, two hundred grains are carefully weighed and dissolved in the manner already described, in twice as much water as will fill the alkalimeter, or any other vessel graduated into a hundred parts. Three ounces of the arsenious solution are measured out and put into a glass jar or tumbler, and tinged with sulphate of indigo. The alkalimeter is now filled with the bleaching liquor, which is added slowly to the arsenious solution, stirring constantly, and watching every drop that is added for the decolouring of the indigo. If the sample be so poor in chlorine that one full of the alkalimeter will not change the colour of the indigo, it may be filled again, and the process continued till the indigo is decoloured, and the whole number of graduations taken to effect this carefully noted—the fewer the number of graduations required, the richer the sample is in chlorine. Now, as every three ounces of the test liquor contains arsenious acid equivalent to 25 grains of chlorine, if the hundred measures effect the change of the arsenious into the arsenic acid, the value of the sample is exactly 25 per cent. ; in other words, every four graduations taken to effect this change indicates one per cent. of chlorine. These equivalents were practically determined, and may differ a little from the theoretical calculation by atomic numbers, but the difference does not vary above half a per cent., and is not of much consequence in practice. The following table will serve as a guide to those who may adopt our proportions :—

| Measures. | Per cent. | Measures. | Per cent. | Measures. | Per cent. | Measures. | Per cent. |
|---|---|---|---|---|---|---|---|
| 150 | 16·66 | 127 | 19·68 | 104 | 24·03 | 81 | 30·86 |
| 149 | 16·77 | 126 | 19·84 | 103 | 24·27 | 80 | 31·24 |
| 148 | 16·89 | 125 | 20·00 | 102 | 24·51 | 79 | 31·64 |
| 147 | 17·00 | 124 | 20·16 | 101 | 24·75 | 78 | 32·05 |
| 146 | 17·12 | 123 | 20·32 | 100 | 25·00 | 77 | 32·46 |
| 145 | 17·24 | 122 | 20·49 | 99 | 25·25 | 76 | 32·89 |
| 144 | 17·36 | 121 | 20·66 | 98 | 25·40 | 75 | 33·33 |
| 143 | 17·48 | 120 | 20·83 | 97 | 25·77 | 74 | 33.78 |
| 142 | 17·60 | 119 | 21·00 | 96 | 26·04 | 73 | 34·24 |
| 141 | 17·73 | 118 | 21·18 | 95 | 26·31 | 72 | 34·72 |
| 140 | 17·85 | 117 | 21·36 | 94 | 26·58 | 71 | 35·21 |
| 139 | 17·98 | 116 | 21·55 | 93 | 26·87 | 70 | 35·71 |
| 138 | 18·11 | 115 | 21·73 | 92 | 27·17 | 69 | 36·23 |
| 137 | 18·25 | 114 | 21·93 | 91 | 27·48 | 68 | 36·75 |
| 136 | 18·38 | 113 | 22·12 | 90 | 27·77 | 67 | 37·31 |
| 135 | 18·51 | 112 | 22·32 | 89 | 28·08 | 66 | 37·87 |
| 134 | 18·65 | 111 | 22·52 | 88 | 28·40 | 65 | 38·46 |
| 133 | 18·79 | 110 | 22·72 | 87 | 28.73 | 64 | 39·09 |
| 132 | 18·94 | 109 | 22·93 | 86 | 29·06 | 63 | 39·68 |
| 131 | 19·08 | 108 | 23·14 | 85 | 29·41 | 62 | 40 32 |
| 130 | 19·23 | 107 | 23·36 | 84 | 29·76 | 61 | 40·98 |
| 129 | 19·38 | 106 | 23·58 | 83 | 30·12 | 60 | 41·26 |
| 128 | 19·53 | 105 | 23·81 | 82 | 30·48 | | |

The above table includes almost the whole range of per centage of the bleaching powder of commerce ; but should the dyer meet with any not included in the table, the per centage may be calculated as follows. As the number of measures is to 100, so is 25 to the answer required. Say, for example, the measure is 160, then 160 : 100 : : 25 : 15·62.

Any of the two methods just described, may be performed in a few minutes; and in a substance that is liable to such deterioration, it is surely of importance that the purchaser have some knowledge of the quality of the article he is purchasing, and that the workmen know something of the strength of the substance they are working with. May not a certain price be fixed to a standard strength of bleaching powder, and to rise and fall according to the per centage of chlorine which it contains, in the same manner as practised with soda ash ? it would at least save much annoyance, and the common complaint, "that the last cask was not so good as the former." The average per centage of good bleaching powder varies from 25 to 30 per cent. Was this average fixed at three pence per pound, which has been the constant price for bleaching powder these some years, then that which contains from 20 to 25 would be $2\frac{1}{2}$d., and from 15 to 20 the price would be 2d. Above 30 per cent. the value ought of course to rise in the same ratio. The adoption of some such plan, we are confident, would be satisfactory to all parties.

To prepare chloride of lime for bleaching, an aqueous solution is requisite. For this purpose, a quantity is put into a large vessel filled with water, and well stirred, and allowed to settle; this is termed the stock liquor. There are no definite proportions for making up this vat; every bleacher makes up his stock-

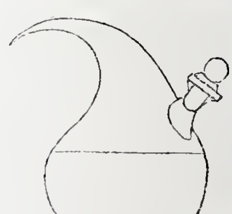
vat to a certain strength indicated by Twaddell's hydrometer; a most fallacious test, as the chloride of calcium, and every other matter which is soluble in water, although it has no bleaching properties, affects the hydrometer. Care should be taken that this stock-vat be excluded from the air as much as possible, as the lime absorbs carbonic acid, and the chlorine being set at liberty, occasions considerable loss. This may be illustrated by putting a little upon a flat plate, and allowing it to stand a few days, when it will be found to have lost its bleaching power altogether.

Having the bleaching liquor prepared, the next process is the preparation of the alkaline leys. Some put in a quantity of carbonate of soda (common soda), or carbonate of potash (pearl ash), into the boiler where the goods are to be boiled, without any previous preparation. This may give a good enough white, but not so permanent; and if any oil be present, carbonated alkalis do not saponify it; it therefore remains in the cloth, and acts as a resist to any colour that may be applied. The alkalis ought always to be made caustic previous to being used for bleaching. This is done by boiling the carbonated alkali with newly slaked lime; the lime combines with the carbonic acid of the alkali, and falls to the bottom, while the caustic alkali remains in solution. Without detailing the various methods practised, some of which are not good, we shall rather give what we consider the best. The carbonate, if potash, ought to be dissolved in no less water than six times its weight; it is better, however, to use ten times its weight. If less than the prescribed quantity of water be used, the potash is not deprived of its carbonic acid. The reason assigned for this singular phenomenon is, that both caustic potash and its carbonate, have a strong affinity for water; and when less than six times its weight, is used, there is sufficient water to supply the carbonate, but not the caustic, and hence, the carbonate is not converted into caustic. The exact quantity of lime is not material, provided there be enough. The lime ought to be added until a little of the liquor diluted with water is found not to effervesce upon the addition of an acid. If soda be the alkali used, five or six times its weight of water will do; but the combining proportion of this substance being less than potash, a much greater quantity of lime is required. The caustic solution is drawn into a vessel which is kept closely covered. Since the soda has been made on the large scale from common salt, a preference has been given to it for manufacturing purposes, owing to its cheapness. It is sold to dyers and bleachers as a dry white powder termed *soda ash*, which is an impure carbonate, and it is prepared as follows:—First, the common salt is converted into sulphate of soda by throwing 600 pounds of the salt into the chamber of a reverberatory furnace already well heated, and running down upon it from an opening in the roof, an equal weight of sulphuric acid of density 1·600 (150° Twaddell), in a moderate stream. Hydrochloric acid (muriatic acid) is disengaged and carried up the chimney, and the conversion of the salt into sulphate of soda is completed in four hours. Second, the sulphate thus prepared is reduced to powder, and mixed with an equal weight of ground chalk, and half its weight of coal ground and sifted. This mixture is introduced into a very hot reverberatory furnace—about two hundred weight at a time; it is frequently stirred until it is uniformly heated. In about an hour it fuses; it is then well stirred for about five minutes, and drawn out with a rake into a cast iron trough in which it is allowed to cool and solidify. This is called ball soda, or British barilla, and contains about 22 per cent. of alkali. Third, to separate the salts from insoluble matter, the cake of ball soda when cold, is broken up, put into vats, and covered by warm water. In six hours the solution is drawn off from below, and the washing repeated about eight times, to extract all the soluble matter. These liquors being mixed together, are boiled down to dryness, and afford a salt which is principally carbonate of soda, with a little caustic soda and sulphuret of sodium. Fourth, for the purpose of getting rid of the sulphur, the salt is mixed with one-fourth of its bulk of sawdust, and exposed to a low red heat in a reverberatory furnace for about four hours, which converts the caustic soda into carbonate, whilo the sulphur also is carried off. This product, if well conducted, contains about 50 per cent. of alkali, and forms the soda ash of the best quality. Fifth, when crystallized carbonate of soda is wanted, the last salt is dissolved in water, allowed to settle, and the clear liquid boiled dowu until a pellicle appears ou its surface. The solution is then run into shallow boxes of cast iron to crystallize in a cool place, and after standing for a week, the mother liquor is drawn off, the crystals drained and broken up for the market. This mother liquor is evaporated to dryness, and forms a very impure soda ash containing about 30 per cent. of alkali.

Owing to various circumstances attending the manufacture of soda ash, its per centage is very uncertain, varying from 30 to 50 per cent. This substance is generally priced according to its per centage. The per centage may be determined by some such means as we have just described for bleaching powder, that is, by having an acid exactly of the strength at which 100 measures of it will saturate 100 grains of caustic soda. "4 ounces avoirdupois of oil of vitriol are diluted with 20 ounces of water, or larger portions of acid and water may be mixed in these proportions. About three-fourths of an ounce of bicarbonate of soda is heated strongly by a lamp for a few minutes to obtain pure carbonate of soda, of which 171 grains are immediately weighed, that quantity containing 100 grains of soda. This portion of carbonate of soda is dissolved in 4 or 5 ounces of hot water, and the alkalimeter—the graduated tube described, and figured above—is filled up to the highest graduation with the dilute acid. The acid is poured gradually into the soda solution till the action of the latter upon blue litmus test paper ceases to be alkaline, and becomes distinctly acid, and the measures of acid necessary to produce that change are accurately observed; say it requires 90 measures. A plain cylindrical jar, of which the capacity is about a pint and a half, is graduated into 100 parts, each containing 100 grain measures of water, or ten times as much as the divisions of the alkalimeter. This jar is filled up with the dilute acid to the extent of 90, or whatever number of the alkalimeter divisions of acid were found to neutralize 100 grains of soda, and *water* is added to make up the acid liquid to 100 measures. This forms a test acid of which 100 measures neutralize and are equivalent to 100 grains of soda, or one measure of acid to one grain of caustic soda." This acid ought to be kept in a well-stoppered bottle. By a curious coincidence, strong oil of vitriol diluted with 11 times its weight of water, gives this test acid exactly; but, as oil of vitriol varies a little in strength, it is better to form the test acid in the manner described, than to trust to that mixture. Twenty-one measures of the test acid should neutralize 100 grains of crystallized carbonate of soda, and 68·5 measures 100 grains of pure anhydrous carbonate of soda.

To test a sample of soda ash, 100 grains are weighed and dissolved in two or three ounces of hot water. The alkalimeter is filled with the test acid, and gently poured into this solution, stirring, as each drop is added, until a piece of blue litmus paper, which may be kept in contact with the liquor, is turned red. The number of graduations taken to effect this indicates the per centage of caustic alkali in the sample.

Another method of using this test acid is by weight. The acid is made to such a strength as one or two grains by weight will exactly neutralize one grain of pure alkali. The vessel commonly used for this purpose is of the annexed form. It is filled with the test acid, and the whole correctly weighed. The acid is then dropped from the small orifice into a weighed quantity of the carbonate until a neutral sulphate is produced. The bottle with its contents are then again weighed; the loss of weight gives, by calculation, the quantity of real alkali in the sample.



Say that every two grains of the test acid are equivalent to one grain of pure soda, and that twenty-five grains of soda ash required twenty grains of acid to neutralize it, the real alkali present will be ten. Now 25 being the fourth of 100, the 10 is multiplied by 4, giving 40 as the per centage of the sample. This method of testing carbonated alkalis is becoming very general; and, provided the operator has a good balance, it is more correct than that with the graduated tube, and equally simple.

The following table, constructed by Dr. Dalton, will be found useful to the operative bleacher, showing the quantity of caustic soda in his solutions, indicated by the hydrometer (not Twaddell's):—

| Density of solution indicated by Hydrometer. | Alkali per cent. | Density of solution indicated by Hydrometer. | Alkali per cent. |
|---|---|---|---|
| 2·00 | 77·8 | 1·40 | 29·0 |
| 1·85 | 63·6 | 1·36 | 26·0 |
| 1·72 | 53·8 | 1·32 | 23·0 |
| 1·63 | 46·6 | 1·29 | 19·0 |
| 1·56 | 41·2 | 1·23 | 16·0 |
| 1·50 | 36·8 | 1·18 | 13·0 |
| 1·47 | 34·0 | 1·12 | 9·0 |
| 1·44 | 31·0 | 1·06 | 4·7 |

As the hydrometers generally used in dyehouses are those known by the name of Twaddell's, which is an arbitrary scale, the densities indicated in the above table may be reduced to Twaddell's scale by cutting off the first figure, and adding a cipher to the last two, and dividing this by 5, except the first number on the table, which is made 1000, and divided by 5. Let us, for example, take 1·18, which is a regular density for the caustic ley, we have $180 \div 5 = 36$, of Twaddell, which is a little more than 1 lb. of caustic soda to the gallon of water, and will require about $2\frac{1}{2}$ lbs. of soda ash of 42 per cent. to the gallon of water, to give caustic soda of this density.

The first operation in bleaching cloth is steeping it in a waste ley or tepid water for a number of hours, generally over night; this is termed the *rot* steep; its object is to loosen the paste and dirt that may have adhered to the cloth during its manufacture. This steep ought not to be hotter than blood heat, otherwise, if oil be upon the cloth, it is not saponified, neither is it so easily taken out after; in all cases when oil is observed, it ought to be taken out by rubbing it with soft soap and cold water previous to putting it into the steep. The goods are thoroughly washed from this steep in the dash wheel, but, if a wheel is not convenient, they are tramped in water, and then washed by rinsing them through water with the hands; they are then ready for the boiler. The boiling ley is made up by taking of the strong caustic ley, prepared as described above, a quantity equal to about six pounds weight of alkali to one hundred pounds weight of cloth, having as much water in the boiler as will allow the goods sufficient play when boiling;—they ought to boil for three hours. When goods are for light delicate colours, such as Prussian blues, the success of a bleach for such colours depends much upon a good boil. The goods are well washed from the boil and allowed to drain; the draining is facilitated by pouring hot water upon them; they are then hanked up, taking out all the twists, and laid into the bleaching liquor as loose as possible. The vessels which contain this liquor are large, made either of stone or wood, and are termed bleaching vats or troughs. To prepare this liquor these troughs are filled with water, and a quantity of the stock liquor added until the required strength is obtained, which is indicated by its action upon the sulphate of indigo, in what is termed the test-glass,—a vessel of this form. It is filled to the mark *a* with the sulphate of indigo;—this indigo is generally supplied by the manufacturers of the powder as test blue;—the liquor is added drop by drop until the colour of the indigo is destroyed; the quantity taken to effect this is denoted by the graduations above; the weaker the liquor the greater the number of graduations required; each of these graduations is termed its degree, two degrees are considered a fair strength for light goods, but, for heavy fabrics, it may be made stronger; they are allowed to steep in this for several hours, varying according to the nature of the goods.


The objections we had to the use of sulphate of indigo as a test in the former case, are equally applicable here. We have found this test to be very uncertain. A much better has been adopted by Mr Crum, a detailed account of which has already appeared in this journal,—see page 361, Vol. I. We cannot help adding, that, so far as our experience goes, it is the best for practical purposes yet introduced to the trade.

To return to the bleaching process.—The goods, being allowed to steep in the bleaching liquor for some hours, are lifted and washed, after which, if they are thick stout goods, they are put into a sour for a little, then washed, and go through the same operations of boiling, liquoring, and souring, as before; but for all common fabrics, we have found it the best practice to *sweeten** the goods from the liquor, bank them anew, and put them back into a new liquor of the same strength, for a few hours, wash them from this, and allow them to steep for an hour in strong sour of vitriol and water—about $1\frac{1}{2}$ pint of the former to four gallons of the latter. There is perhaps no single branch connected with the art of dyeing upon which there is more difference of opinion than bleaching. Every one has some peculiarity of his own; but, when the peculiarities are all compared, the difference is in general only nominal. One thing may be noticed; namely, the necessity there is of washing well from the liquor before souring, as any lime remaining upon the cloth will be formed into an insoluble sulphate, and resist the dye. Some maintain that this is of no consequence; in our opinion, it depends wholly upon the colour which is to be dyed on the cloth. We have found that light pinks, light greens, light lavenders, and sometimes light blues, when not washed well from the liquor, were often full of white spots, which we ascribed to that cause; but, for other dark shades, we found no difference, and for colours to be dyed with the bichromate of potash, (chrome,) such as yellows, ambers, and orange, we seldom give them any sour, only washed from the first liquor, and then dyed.

Cotton, in the hank (yarn), when to be finished white, goes through the same process as cloth, with the exception of the *rot* steep; but, for dyeing, a quicker operation is adopted. All cotton yarn must be boiled in water for three or four hours previous to being dyed. Every ten pounds weight—constituting what is termed a bundle—is divided into six equal numbers of *spindles*, and hung upon wooden pins about three feet long and two inches thick; this is termed *sticking*.

The stock-liquor for yarn is generally prepared in a cask or pipe, containing about 120 gallons of water; to this is added about 20 lbs. of good bleaching powder, stirred, and allowed to settle. A small tub, of a size in which a bundle is wrought freely, is termed a ten pound tub; this is filled nearly two-thirds full with boiling water, and a bucket or *pailful* (about four gallons) of the stock liquor is added. The bundle is now let down as quick as possible, and turned over for about ten minutes, after which it is put through a second tub of the same size, with water made a little sour by adding about an imperial gill of vitriol, and wrought for about five minutes. Being then well washed, it is ready to be dyed almost any light shade. By this method two men can bleach and wash two hundred pounds weight of yarn in about three hours—what, by the other process of boiling, steeping, and scouring, would have occupied two days.

Having detailed the present method of bleaching cotton goods for dyeing, we may say a little upon the chemical nature of these processes, previous to the discovery of the elementary nature of chlorine. When that substance was considered a compound of muriatic acid and oxygen, it was thought that the acid parted with its oxygen, which bleached by the same means, but more rapidly, as the air which we have described under croft bleaching. When the true nature of chlorine was discovered, the theory was somewhat changed; finding, as was then supposed, that chlorine did not bleach except water was present, it was considered that the chlorine united with the hydrogen of the water forming muriatic acid, and the liberated oxygen bleached, as described. Thus oxygen was still the bleaching agent.

The above theory is still maintained and supported by various analogies. We shall quote the following from Gregory and Liebeg's edition of Turner's Chemistry, new edition, 1840:—"One of the most important properties of chlorine is its bleaching power. All animal and vegetable colours are speedily removed by chlorine, and when the colour is once destroyed, it can never be restored. Davy proved that chlorine cannot bleach, except water be present; thus dry litmus paper suffers no change in dry chlorine, but when water is admitted, the colour speedily disappears. It is well known, also, that hydrochloric acid (muriatic acid) is always generated when chlorine bleaches. From these facts it is inferred that water is decomposed during the process, that its hydrogen unites with chlorine, and that decomposition of the colouring matter is occasioned by the oxygen liberated. The bleaching property of binoxide of hydrogen, and of chromic, and permanganic acids, of which oxygen is certainly the decolouring principle, leaves little doubt of the accuracy of the foregoing explanation."

* Building the goods on a drainer, and pouring water upon them till the water ceases to taste of liquor as it comes from them, is termed *sweetening*.

Another theory has been advanced, and equally, if not more tenable, by which the chlorine is supposed to act directly upon the colouring matter. The following is from Dr Kane's work:—"Formerly it was considered that water was necessary for this bleaching, and that the chlorine combined with the hydrogen, while the oxygen of the water being thus thrown upon the organic substance, oxidized it, and formed a new body, which was colourless. I have shown, however, that this is not the case, but that the chlorine enters into the constitution of the new substance formed, sometimes replacing hydrogen, at others, simply combining with the coloured body, and in some, the reaction being so complete, that its immediate stages cannot be completely traced."

This theory is also supported by several analogies, such as the action of chlorine upon indigo already noticed; but which of the changes alluded to by Dr Kane takes place during the bleaching of cotton, is not yet known. Chloride of lime, says the same author, does not bleach, except an acid be present to combine with the lime, and set the chlorine at liberty; but this is only conditional. It is true, that if blue litmus paper be put into a solution of newly dissolved chloride of lime, it is not bleached; but if the solution be allowed to remain in contact with the air for an hour or two, the lime combines with the carbonic acid of the atmosphere; and if the blue litmus paper be put into this solution, it is instantly bleached by the liberated chlorine. Cotton that has not been boiled in alkalis, is acted upon as the litmus paper in both cases; but if the cotton has received a good alkaline boil, and is well washed, the bleaching process goes on although the bleaching powder be newly dissolved. This shows that the alkaline leys effect a change upon the colouring matter. The nature of this change we are not as yet prepared to state: several opinions have been given, but they are hypothetical, and some of them contrary to the changes which are supposed to follow.

Whenever the cloth is put into the bleaching liquor, there are acids formed, the principal of which is the hydrochloric; but whether it is from the chlorine, combining with the hydrogen of the water, or the colouring matter of the goods, we cannot say,—the latter we think most probable. Our opinion is, that the chlorine combines with the hydrogen of the colouring matter; and according to a law we have several times alluded to, the remaining elements of the colouring matter form a new substance, which is soluble, and thus the whole colouring matter is taken off the cloth. In vats, where several hundred pounds weight of cotton have been bleached before changing the liquor, there is evidence of more substances remaining than merely a solution of muriate of lime; but what these are, we dare not as yet venture to assert. That the bleaching of cotton depends upon either oxygen or chlorine combining with the colouring matter, forming a colourless oxide or chloride, is not consistent with the fact, that bleached goods are lighter than goods merely boiled.

Such is an outline of the processes of bleaching cotton goods for dyeing, as practised in most dyeworks at the present day. Woollen and silk are bleached by exposing them after being boiled or scoured, to the vapour of sulphurous acid; but this is not done upon goods that are to be dyed.

## IRON FOUNDING.

### SECTION III.

The next branch of the subject which falls under consideration, is the manufacture of works in dry sand, usually called dry-sand moulding. This department embraces, generally, the manufacture of pipes, columns, shafts, and other long bodies of a cylindrical form, or approaching to it. Dried or baked sand, as was formerly stated, consists of loam called pit sand that has already been used in structures of loam work, mixed with fresh sand. Dry sand acquires a very firm and open consistence by the expulsion of its humidity by heat, and it is found to be much better adapted to the purposes above-mentioned than green sand.

The mechanical part of the process of moulding in dry sand, is the same as in the case of green-sand work. In general, no coal-powder is mixed with this sand. When the mouldings are finished they are transferred to drying stoves, in which they are exposed twelve hours or upwards, as occasion requires, to the action of a strong heat, till their humidity is banished. The experience of the moulder must be his guide in so mixing the materials at his disposal, as to produce the most accurate form of mould when finished, which shall also be sufficiently porous. Such moulds permit a readier egress for the gases generated by the casting, than green sand; generally, also, the castings turned out are less vesicular, and smoother upon the surface.

When the castings are large, and especially if they are tall, the hydrostatic pressure of the metal upon the sides of the mould is counteracted, both by the firmness of the sand, and by the wedge-shaped form of the boxes. To aid the resistance, the sides are feathered along the outside, affording additional abutting surface for the sand. Fig. 1 is a view of one-half of a moulding-box for pipes, the other half being an exact counterpart. Fig. 2 is a cross section, showing parallel sides. Fig. 3 is a similar section of a wedge-shaped box for heavier castings. It is formed with flanges along the sides, which meet those of the other box. By means of these flanges the two halves are bound together by glands. Fig. 4 is a cross section of a flanged rib. A pair of swivels is attached to the ends of each box, by which they are raised and inverted as occasion requires. Another pair is usually fixed on the middle of the sides, upon which, when the boxes are hung, they may turn in a direction perpendicular to the preceding, that they may be set vertically at their destined position, which is commonly in a pit dug to receive them.

*Fig.* 1

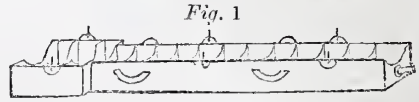


*Fig.* 2 *Fig.* 3 *Fig.* 4

Pipe moulds are always either set upright on one end, or laid in a position very considerably inclined, on a bed of sand prepared for the boxes, at an angle of 30° or 40°. When practicable, the larger sizes of pipe moulds are placed in a vertical position, as well as all other comparatively tall articles; the general object being to raise all the slag that collects on the surface of the iron, while being poured, clear of the cast into the gate-way, securing thereby soundness to the cast. It is evident that, were pipes, for example, cast horizontally, the metal, at any given period in the running, would expose a large horizontal surface, which is unfavourable to the soundness of the casting, and impurities besides would infallibly lodge in the upper portion of the mould. Both of these objections are removed by setting the mould in an inclined or a vertical position.

In proceeding to describe the method of forming moulds for pipe castings, it will be necessary, in the first place, to describe the construction and the formation of the cores. In the constructing of pipe moulds, as well as the moulds of all other large hollow articles, it is necessary that the core be both rigid and porous; these conditions are obviously necessary, when it is remembered that the least flexibility in the core must alter the thickness of the casting; besides, that the core, being itself so much confined externally by the liquid metal when poured, the ends alone serving as channels of escape for the interior air, must offer within itself facilities for the escape of the gases generated. Both of these objects are accomplished by employing a tube of iron, forming the centre of the core, and perforated at regular distances for the escape of the air. For the smallest sizes of cores common gas-pipes are used, with holes drilled in them at about nine inches distance, on alternate sides. Wrought-iron tubes of a larger size are employed for larger pipes; and, for the largest sizes, cast-iron pipes are adopted, with rows of oblong holes cut at equal distances for ventilation. These cast-iron *core-bars*—the general appellation to all the varieties enumerated—have wrought-iron double knees fitted and bolted to their extremities for the purpose of sustaining journals or bearings, upon which they may be turned on their own axes. The hollow ends of the wrought-iron pipes are formed square to receive a winch by which they also may be made to turn upon themselves, the use of which operation will speedily appear.

Again, a core-bar for a pipe of any given inside diameter is selected two or three inches less in diameter, with the view of providing for hay-rope and loam, by which the core is made up to the necessary thickness. The loam, which forms the external coat of the core, is made as open as practicable by augmenting the usual proportion of sharp sand in its composition. The hay also, which is simply twisted into ropes to facilitate its applica-

tion to the core, fulfils the important office of a conducting medium for the air forced through the loam, leading it from all parts of the surface to the vent holes in the core-bar. The method of applying the hay and the loam is simple. The core-bar is rested by its pivots on two iron tresses, the upper edges of which are formed with corresponding semicircular or triangular dentations, to receive the pivots. Thus placed, the core-bar is caused to revolve by a crank-handle applied at one extremity, during which operation the rope is led on regularly along the bar from end to end, and fastened there. It must be tightly done, as any slackness in the rope will permit it to yield when subjected to the pressure of the iron, which has the effect at least of altering the form of the pipe, if, as in some cases, it do not break up the core, and spoil the casting. Before finishing the core with loam, the hay receives a slight coating of it all over, as a cement to smooth down the surface. This being dried, for the succeeding application of the loam, a loam-board is necessary. This is a board of sufficient length to rest upon the tresses which support the core. Along this board is laid the loam intended to form the core. The edge of the board is cut exactly to the form of the core, being, indeed, a half skeleton reversed. This board being then set along-side the bar, and weighted down at the extremities, at a distance of the half diameter of the pipe from the centre, it is evident that, as the core-bar revolves, and the loam is pushed over upon it, there will ultimately be formed a coating of loam completely enveloping the coat of hay, which shall also possess the figure of the core.

In this manner is the core formed. The annexed figures will

*Fig.* 9

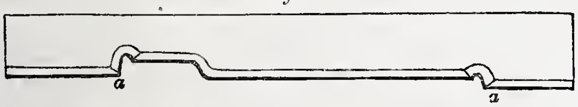



*Fig.* 5

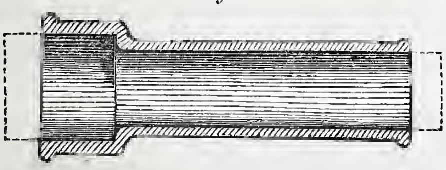


*Fig.* 6

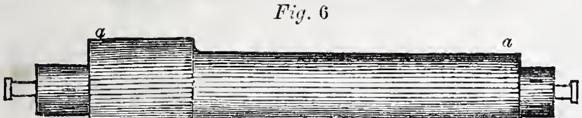



*Fig.* 8.

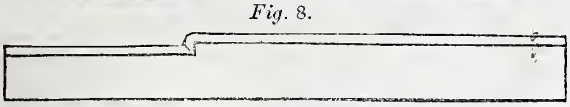
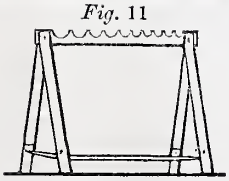


*Fig.* 7

*Fig.* 10

*Fig.* 11



illustrate the process. Fig. 5, is a longitudinal section of a pipe, in which the exterior and interior outlines are represented. The dotted lines at each end indicate the additions necessary in the pattern as core-prints. Accordingly, Fig. 6 represents the core as formed upon the bar before described, the core being prolonged to be supported in its bearings formed by the pattern, though it matters not if it should be longer than necessary. Fig. 7 represents the core-bar with its pivots at the ends, and the vent holes scattered over its surface. Fig. 8, shows the loam board employed in constructing the core of the pipe, (fig. 6). It will be observed to follow the outline of the core. Fig. 9, in like manner, represents the loam-board that would be required to form the pipe itself, (fig. 5,) were there no wood pattern of it. In such a case an additional coat of loam is run by means of it upon the core, (fig. 6). In this way, it is evident, a loam pattern is at once formed. In setting the board, the parts *a a*, (fig. 9,) will apply to the same parts *a a*, (fig. 6), which, in so far, serve for a gauge. The misplacing of them exactly opposite each other is to be guarded against, as there is not the same security for their being correctly placed. Before receiving, however, the additional thickness, the core must be washed over the surface with charcoal and water, that the thickness may be easily separable afterwards, and also thoroughly dried in the stove. In the mean time, having finished and dried the loam pattern, it receives in like manner a wash with charcoal water, and is ready to be moulded. This being done in the usual manner, the thickness is peeled off, and the naked core replaced in the mould. To aid the stiffness of the core, steeples are planted here and there over the surface of the mould, as explained in last Article, which resist any undue tendency of the core on one side or another. Fig. 10, is a cross section of the body of the core. There are three concentric plies—the inmost, which is the core-bar, with several vent-holes in section, and the cross knee at the end; the next is the hay, and the external coat is the loam. Fig. 11, is a sketch of one of the iron tresses used in the work.

All wood patterns of pipes are constructed in two halves, which have two or more pins in the one entering corresponding recesses in the other, to prevent their shifting when put together and moulded. In proceeding to mould a pipe, a laying-down board is usually employed, which is simply a straight piece of wood as long and as wide as the moulding-box. Upon this board one-half of the pipe is laid with the flat side down, the box is placed over it, and rammed; the whole is inverted, and the board lifted off. The remaining half of the pipe is set upon the imbedded half, and the upper box over it, and linked to the under one; the upper box being rammed, the patterns are loosened, as we have in other parts described, and longitudinally also by blows upon the ends. The boxes being parted, the patterns removed, and the moulding blackwashed with blackening, the core is set in, and the box closed. Small pipes, when there are several to be cast, are usually moulded in pairs in one box, when green sand is employed as a moulding material. The metal is poured in at one entrance, which branches to each moulding; shortly after which streams of aqueous vapour mixed with hydrogen and other gases, arising from the imperfect combustion of the charcoal and hay, are expelled from the extremities of the core-bars, sometimes resolving themselves into luminous jets. Soon after the metal is poured, the castings are turned out to cool; after which the core-bars are drawn from them, which is a comparatively easy task, as the hay has been for the most part consumed, and of course occupies less bulk. Long small rods of iron are next introduced, with scrapers formed on the ends of them, and they are drawn from end to end, to clear the interior of the pipe of the remains of the core.

In the moulding of the various lengths of pipe that are required for use, one pattern is made to answer. Pipe patterns are generally made nine feet long, of which an appropriate number of lengths are cast, when more than nine feet of piping is required. But shorter lengths also are frequently wanted, when of course the full length of the pattern would not be proper. The moulding, therefore, is cut to the required length; in technical language, the pattern is cut in the sand. In such a case, some preparation is necessary to form a new bearing for the core. For this purpose, two semicircular pieces of wood, of the diameters of the mould and the core respectively, are sprigged together end to end, as in fig. 12; and it is obvious that by placing the larger piece in the mould in each box at corresponding parts, and ramming fresh sand about the smaller, the bearing will be formed. In like manner, if the piece of pipe terminate in a flange, the flange having been moulded in its place, a half flange of the same dimensions, with a half core-print on it, as at fig. 13, is set into the mould, and the bearings for the core made up.

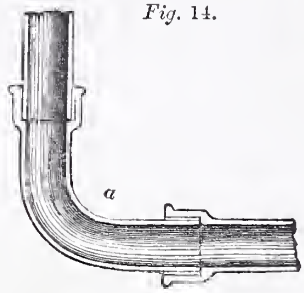
*Fig.* 13.

*Fig.* 12.

Small perpendicular branches required to be made upon pipes, are cast, either horizontally or vertically, as may best suit the form of the box. In the latter case, the branch pattern is set loose upon the pipe, projecting upwards between the ribs of the box, and having been moulded, it is drawn out, and its core set in upon the pipe core, and the whole covered in.

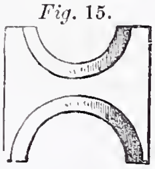
Besides straight pipes, others have often to be cast of different forms, requiring peculiar treatment. In arrangements of pipe works there is usually a number of knees or bends in their construction. These bends are usually cast separate from the straight portions of pipe, having facets upon them by which they may be afterwards joined to the pipes. The annexed, fig. 14, is a longitudinal section of a square knee in a line of pipes, showing the method of junction by spigot and facet. The term *spigot*, it may be as well to observe, is applied to the small semicircular ring upon the plain end of a pipe, as may be seen in fig. 5; *facet* denominates the cup mouth on the other end for receiving the spigot. There are usually patterns and core-boxes for pipe bends of the usual square-knee shape, in which case they are moulded in green sand. In the absence of patterns, however, for these and for other varieties of short piping, they are *swept up* in loam, the core within the "thickness."

*Fig.* 14.



In this process, the first point is to have a level iron plate set, upon which the work is to be done. Like patterns, the loam work is formed in two halves. The cores are executed in the first place, and, when dried, the thicknesses forming the exterior of the casting are next laid on. Fig. 15 represents the gauge usually employed in forming small pipe work. As already said, the work is done in separate halves, for which purpose semicircular cuts are made in the gauge, of which one is smaller than the other, being respectively the measures of the core, and of the additional thickness.

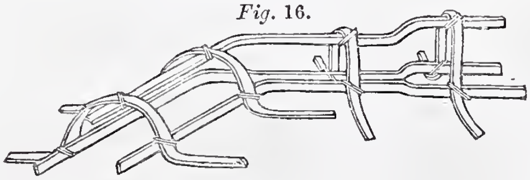
*Fig.* 15.



For example, suppose the bend, figured at sketch 14, is to be constructed, a small square rod of iron is bent to the form of the knee, against and along the side of which the gauge is moved. A quantity of loam being laid on the plate in the line of the pipe to be formed, the gauge in its progress fashioning the loam to its own form. When the two half cores are in this manner swept up, they are well dried and blackwashed, after which the gauge is inverted, and additional loam being laid on for thickness, it is likewise shaped to the form of the pipe. The junction of the body of the pipe and the facet, which are of different diameters and of course require different sweeps, is scraped out by a file when the loam is dried; the head on the end of the facet is either formed by a pattern applied to the moulding, or cut out of the *cope*.

The loam pattern being thus completed in two halves, dried and blackened, it is bound together at two or three places by iron wire, and bedded half into a sufficient quantity of old loam mixed with water and laid over the iron plate. The boundary of the loam is built up with fragments of cake loam. The bed being smoothed off on each side and dried, a layer of the same watered loam is applied to cover in the upper half of the pattern. As this upper layer has afterwards to be lifted whole, it requires to be strengthened by the addition of irons. With this view, pieces of rod iron, accommodated to the form of the moulding, are laid on among the wet loam transversely and longitudinally, and bound together by wires at the angles constituting a kind of skeleton frame-work (fig. 16), for the *cope*, as it is termed, or upper structure. The irons are then covered in with old loam, which is smoothed over them, and the whole is for the last time thoroughly dried.

*Fig.* 16.

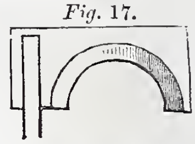


The building of the work being now completed, the next step is to undo it to clear out the thickness. The cope is lifted off carefully, leaving the rest of the work behind it, and this complete separation of the parts is one object for which the blackening or charcoal water is applied. In the same way the pattern is lifted out from the bed of the moulding. The thickness is easily broken off the core, leaving the latter entire; the halves of which are next bound by wire, and replaced in the mould, stayed by bearings at the ends, and by steeples intermediately. The cope is replaced, guided to its former situation by intentional irregularities on the junction surface, and is bound by wires laying hold of the skeleton, to the under plate.

The gate is formed in the usual manner by a pin stuck in the cope while being formed.

For some small pipes, such as bends which are uniformly circular, circular iron-plates are frequently made to the same centre on both sides, so that when the cores are swept up on them, they lie concentric with each other. The edges of the plate will therefore serve for guides in the making of the core. For this purpose, the gauges are made as in figure 17, having a piece of wood nailed on and projecting downwards. By sliding this gauge along the interior or exterior edge as it may be adapted for them, the pipe is formed as before.

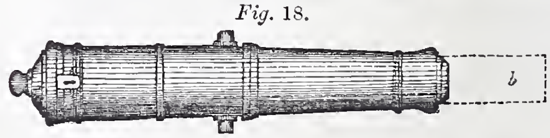
*Fig.* 17.



The manner of moulding and casting columns of every variety, and other long hollow work, is essentially the same as that now described for pipes; it is unnecessary to extend farther our details upon these articles. We shall conclude this section with a notice of the method of casting guns and carronades, taking for example a nine pounder gun, six and a half feet long, with a bore of 4·2 inches in diameter.

Fig. 18 is a representation of a nine pounder gun. Patterns made of wood may be employed where there exists no great demand for castings for them; but in the prospect of extensive supplies being expected to be furnished, it is a much superior method to construct iron patterns, which, when turned and polished in the lathe, always preserve their figure, and of course always produce good uniform castings.

*Fig.* 18.



As it is desirable to have these iron patterns as light as possible, consistent with the straining to which they may be subjected, they are made hollow throughout. It is then the business of the moulder, in the first place, to form a hay-and-loam pattern in a manner similar to that in which pipe patterns of loam are made.

As it is of great importance to secure solidity to gun-castings, they are made without bore, and with an additional length on the muzzle end, as indicated by the dotted lines which of course is provided for in the pattern. When the mould is formed and set on end in readiness for being cast, the metal is poured into it slowly at first, increasing in flow as the mould is filled to the top, which is left open. Into this additional portion then, all the sullage rises that is collected during the course of the pouring, leaving the body of the gun-casting generally in a pure state. The moulding sand adheres very firmly to the casting, and requires to be knocked off by hammer and chisel afterwards in the course of dressing.

In preparing for boring the gun, the head or sullage piece is in the first place cut off close by the muzzle of the gun. A proper face is thus prepared for starting the bore, which is cut out of the solid.

It will be observed, on examination of the drawing, that the sullage piece is less in diameter than the rest of the casting. Formerly, lumps of metal of almost double the diameter of the

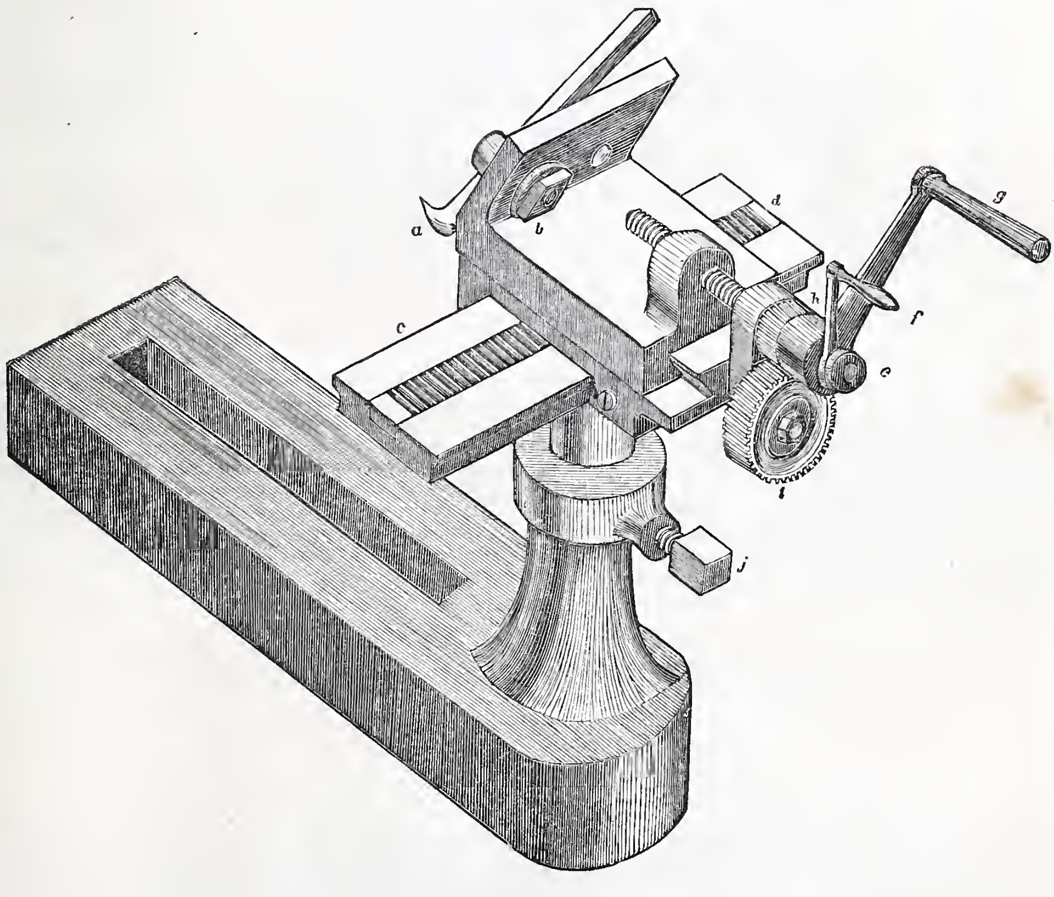
muzzle, were cast upon the end, in the belief that the exposure of such a considerable surface would draw up the sullage more readily to the upper part. This mode, notwithstanding the alleged advantages, defeated its own end; for it is easy to see that the body of the gun is opposed by its taper to the large head, being connected by the comparatively small muzzle. Accordingly, in course of cooling, as the shrinkage which attends the cooling proceeds, the neck or muzzle will be forcibly drawn between the extremities, and will assume, in consequence, a vesicular structure, which is fatal to the perfection of the bore and the strength of the metal. This cause of imperfection in gun-castings, vanishes in the comparatively small size of head now adopted, as it offers no opposition to the natural law of contraction in connection with decrease of temperature, while it, at the same time, affords free scope for the ascent of the sullage.

Our next step will be to enter upon the business of *loam moulding.*

## SHANKS' PATENT SLIDE-REST.

*Explanation of the Drawing.*

*a*, The tool, of the ordinary shape, called a "heel tool."
*b*, The eye-bolt, for fixing the tool to the upper slide of the slide-rest, in a position nearly perpendicular.
*c*, The bearer-slide, having a wrought-iron rack, *d*, inserted in its upper surface, throughout its whole length.
*e*, The screw for giving the transverse movement to the upper slide, on the end of which is fixed the small handle, *f*.
*g*, The large handle, having the pinion, *h*, attached to it, and which revolves on the outside of a tubular axis, not shown. The screw, *e*, works inside of the same tubular axis.
*i*, Wrought-iron wheel, for reduction of motion, having a spindle extending to the rack, *d*, with a pinion into which it works, for giving the longitudinal movement.
*j*, The ordinary rest socket.

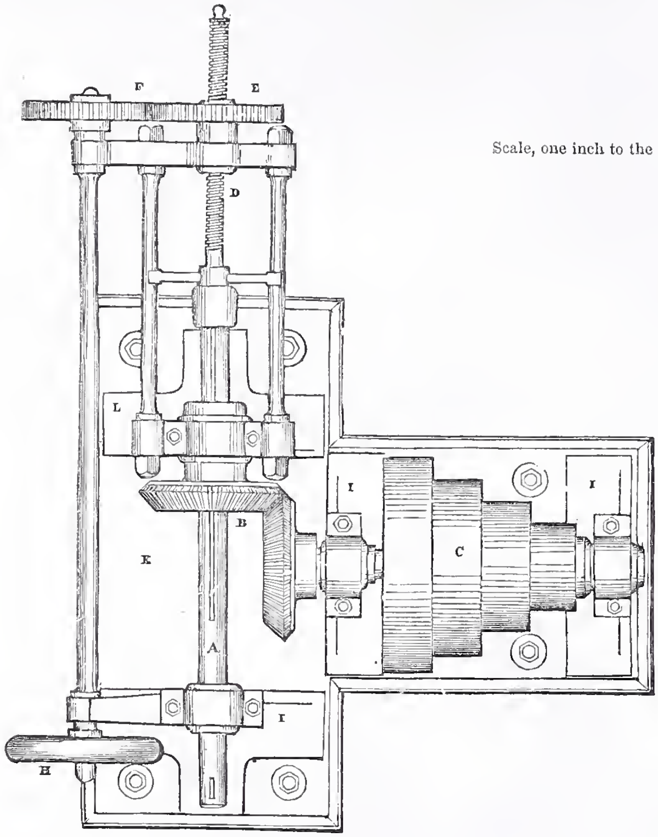



The advantages of this patent slide-rest over all others, independent of its complete adaptation to any species of lathe, are—first, the improved manner of fixing the tool nearly perpendicular, and in such a way as to permit its being raised or lowered at pleasure, without disturbing the parallelism of the rest; at the same time, it is capable of being placed at the most advantageous angle for cutting, by the movement of the eye-bolt that fastens the tool. Second, by having both handles in front, and revolving on the same centre (the one through the other), its applicability for ordinary work is evident, by having the movement of both handles free of the headstocks in sliding or surfacing.

# SMALL VERTICAL DRILLING AND BORING MACHINE.

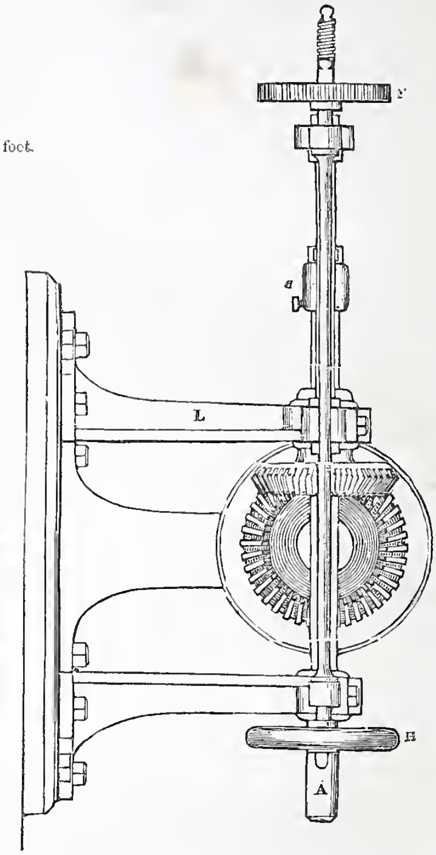
By Messrs. James Nasmyth & Co.

*Fig.* 1.—*Front Elevation.*




Scale, one inch to the foot.

*Fig.* 2.—*Side Elevation.*




A is the boring spindle, driven by a pair of bevel-wheels B; the one carried upon the spindle as an axis slides freely upon it, permitting it freely to ascend and descend in obedience to the feed motion. The wheel is prevented from revolving upon the spindle by a feather in the eye of the wheel, which slides in a longitudinally grooved cut in the spindle. The other bevel-wheel is fast upon the axis of the driving cone C. The vertical motion of the spindle is accomplished by the screw D, which works in the centre of the wheel E, bushed with an internal brass screw. The wheel F, which gears into E, is driven by the rod G and hand-wheel H. By this arrangement, it is clear that the wheel H, being turned one way or the other, upward or downward motion of the spindle is produced by the action of the internal screw in the wheel E upon the screw D. The four brackets I I I I sustain the bushes in which the boring and driving spindles turn. K is the sole upon which the brackets are bolted; it is fixed to the wall by stud-bolts and nuts. The spindle and screw are connected by the collar *a*, which carries a cross-piece extending between a pair of parallel guides, seen in Fig. 1.

# ANALYTICAL TABLE OF MECHANICAL MOVEMENTS.

## PLATE II.

*Description.*

43. Is an arrangement by which the inclined disc or plate, by circular motion, produces an alternate traverse motion in the horizontal shaft to the left.

44, 45, 46. Are various methods of producing rectilinear motion from circular.

47. Is a form of eccentric for producing a uniform traverse.

48. By the revolution of the circular plate, the perpendicular lever to the right is made to vibrate by the pin moving in the eccentric slot.

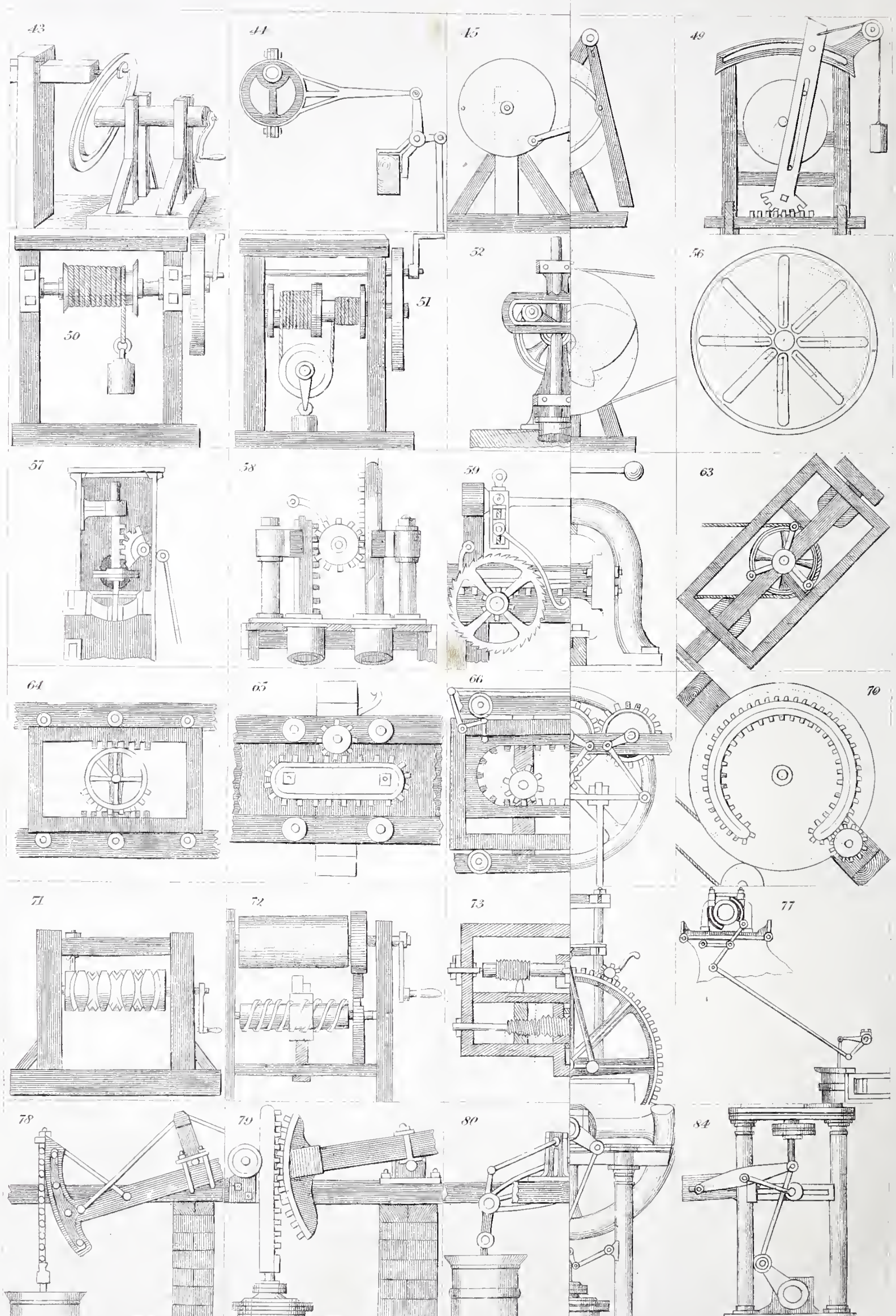
49. By the revolution of the circular plate, in which is a fixed pin moving in the slot in the upright bar, which bar turns upon the centre at the bottom, both ends of the bar are made to traverse, producing alternate rectilinear motion in the horizontal bar at the bottom, and also alternate perpendicular motion in the weight.

50. A common windlass.

51. A Chinese capstan. This machine was introduced from China. By the revolution of the handle, motion is communicated from the pinion to the wheel which turns the barrel, one part of which is thicker than the other. One end of the same rope is

TAB

CIRCULAR MOTION CONVERTED INTO RECTILINEAR MOTION AND VICE VERSA



coiled round each half of the barrel, so that as by the revolution of the barrel it is unwound from the one, it is wound upon the other. A weight is suspended from a pulley, through which the bight of the rope passes. When the rope is wound round the large half of the barrel, the weight will be raised, and *vice versa*. Its advantage is, that a certain amount of power will overcome a greater resistance than can be done with the common windlass. The principle will be more minutely explained in our treatise upon the wheel and axle.

52. The revolution of the pulley at the back moves the shaft on which the crank is fixed. The crank moves in the slot placed upon the vertical bar, producing vertical motion for working a pump, or other suitable application. This principle is sometimes used in small steam-engines. The vertical bar may represent the piston rod, which, by moving the slot (in which the crank moves,) up and down, produces circular motion.

53. Is the late Mr White's proposed method for pumping by rotatory motion. The wheel, carrying a rope connected with the pump rod, is placed loose on a revolving shaft, which shaft carries a fixed projection, taking into a vibrating catch attached to the wheel near the circumference, so that in the position here shown, the wheel and rope are carried along with the shaft; but as soon as the vibrating catch comes in the position shown by the dotted lines to the right, it is relieved by striking against a fixed stud, and the wheel being thereby liberated, the weight of the pump rods carries it back till again caught by the projection from the shaft.

54. Represents the ordinary arrangement for lifting stampers by circular motion, commonly used for pounding flint, pressing seed, &c.

55. Is an example of a cam, eccentric, or tappet piece, by which any rectilinear traverse may be produced, and varied in speed or amount according as its shape is varied.

56. Represents a metallic plate with radiating slots cut in it, and the dotted lines represent slots cut in a similar plate at the back. Suppose bolts or rods passed through the aperture made by the intersection of the slots, they will be held stationary while the two metallic plates remain at rest; but if either of the plates is revolved, the bars or bolts will be traversed in the direction of the straight slots. This principle has recently been patented by Mr Samuel Hall, for reefing paddle-wheels.

57. By motion of the rod to the right, attached to the short lever at the back, alternated circular motion is communicated to the toothed sector which communicates alternate motion to the upright bar. This was the plan originally used by Watt in working the valves of his steam engine.

58. By the alternate motion of the handle, motion is communicated by the pinion to the racks. This is applied in working air pumps used in scientific experiments.

59. Represents the feeding apparatus for a vertical saw frame. By the revolution of the crank at the lower part of the figure, alternate motion is communicated to the horizontal arm of the bell crank lever. By this means motion is communicated to the catch attached to the vertical arm of the lever, which catch communicates motion to the ratchet wheel, upon the shaft of which is a toothed pinion, working in the rack attached to the side of the travelling carriage in which the logs are placed to be cut.

60. By the revolution of the wheel, the horizontal bar is made to traverse; and is pressed close to the teeth by the spring at the right hand.

61. Is the moveable head of a turning lathe. By turning the wheel to the right, motion is communicated to the screw, producing rectilinear motion on the spindle in the end of which the centre is fixed.

62. Represents a punching machine. By turning the lever at the top, the screw is turned round, and the punch pressed with great force into the bolster. By reversing the motion, the punch is raised.

63. The circular motion of the pulley at the back of the figure produces circular motion in the three wipers that revolve within the frame. These wipers act alternately on the projecting pieces, and make the frame traverse.

64, 65, 66. Are alternate traverse motions, produced by the revolution of the pinions.

67. In this figure the ratchet wheel is fixed on the shaft seen in the centre; but the spur wheel, to which a clip is attached, runs loose on the same shaft, so that its rotatory motion will only act on the rack into which it geers in one direction, namely, when the click holds on the ratchet. At the back of the spur wheel is another similarly arranged, with a click and a ratchet wheel, and geering into the opposite rack, which is not on the same plane. Thus the alternate traverse of the perpendicular rack-piece will produce continuous circular motion in the shaft which carries the wheels.

68. Represents Mr White's ingenious method of converting circular to rectilinear motion, by the revolution of the internal wheel, which being one half the diameter of the circular rack in which it geers, any point on its circumference will describe a straight line. This arrangement has been applied to the piston rod of small steam-engines.

69. Supposing the fly wheel in this figure to revolve, a rectilinear motion will be imparted to the perpendicular shaft; this arrangement was used as a parallel motion by Cartwright in his steam-engine.

70. The pinion having motion on its axis, as also liberty to traverse in the slot, shown by dots, the large double rack will be revolved backward and forward on its centre, according to the interior or exterior position of the pinion, and the band shown at the periphery of the large rack will produce an alternate rectilinear traverse.

71. Represents a horizontal cylinder, having two reverse threads or grooves cut on it, which necessarily intersect twice in every revolution. Under this arrangement, a point inserted in the groove will be traversed from end to end, at a speed dependent on the revolution of the cylinder. This principle has been applied in the platen steam printing press.

72. A machine for cutting screws by means of the leading screw on the lower barrel. The pitch of the screw to be cut may be varied by altering the wheels seen on the ends of the barrels.

73. Is an arrangement for a similar purpose. Upon the horizontal bar at the bottom of the figure two screws of different pitches are cut; the screw to the right turns round in a fixed nut, by which means the bar is made to traverse at each turn, a place equal to the pitch of the screw. The smaller screw works into a nut which traverses through a space equal to the difference of the pitches of the screws. This nut is attached to a rest in which a cutter is fixed, the point of which cutter acts upon the upper cylinder, which revolves at the same speed as the lower screws. By this means, a screw is cut upon the other cylinder equal to the difference between the pitches of the screws on the lower cylinder.

74. The upper figure is an end view, and the lower a section of 73.

75. By the horizontal motion of the lever, rotatory motion is communicated to the upper disc, in the under surface of which are two holes to receive the ends of two short bars, one of which is seen standing obliquely between the upper and lower discs—the other bar is behind. The lower ends of the bars are placed in holes in the upper surface of the lower disc. In the rotatory motion of the upper disc, the two bars are brought into a perpendicular position, thus forcing down the lower or raising the upper disc, and anything to which they may be attached. This has been used in letter presses, to produce the necessary pressure upon the platen.

76. A small packing press. By the revolution of the handle, motion is communicated by the pinion to the quadrant, to the lower arm of which a connecting rod is attached, the other end being attached to the lower plate of the press. As the lower arm of the quadrant is raised, motion is necessarily communicated to the lower plate of the press.

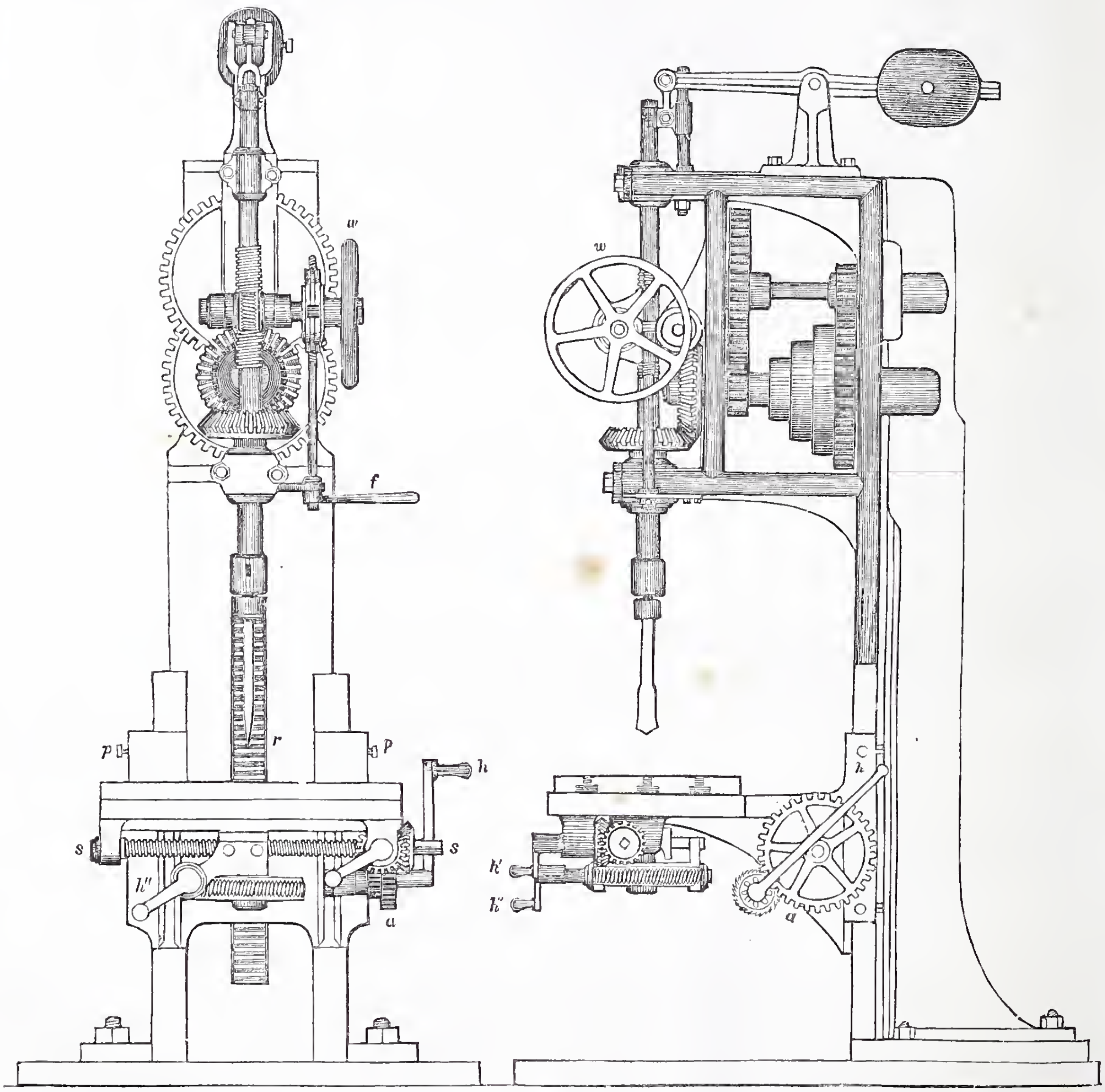
77. Is the apparatus by which motion is communicated to the expansive valve of the steam-engine. By the revolution of the cam fixed upon the shaft, the end of which is shown at the top of the figure, motion is communicated to the lever, in the upper end of which is a friction pulley seen bearing upon the cam. Motion is transmitted by the connecting rod from the other end of the lever, to the small bell crank lever at the bottom. From the other end of the bell crank lever a rod is attached to the expansion valve.

78, 79, 80, 81, 82, 83, 84. Embrace all the varieties of parallel motions that are commonly used in the steam-engine. Their minute and separate consideration must come under our treatise upon that machine.

# SELF-ACTING DRILLING AND BORING MACHINE.

By Messrs. Joseph Whitworth & Co., Manchester.

The frame of this machine is of cast-iron, and is strongly bolted to a sole-plate of the same material. The main gearing is the same as that of a lathe with a back speed. On the end of the cone-axis a bevel wheel is fixed; this gears into another bevel wheel through which the spindle passes, and upon which it slides as the spindle rises and descends, but is prevented from turning upon it by a feather-catch and groove. The down motion of the spindle is obtained by the screw upon it working into two worm-wheels—one on each side of the spindle. By this means any amount of down-




ward pressure may be communicated to the spindle; for, if the worm-wheels were absolutely fixed, it is clear that the spindle would descend through a space equal to the pitch of the screw upon it each revolution it made; and, on the other hand, were the wheels perfectly free to move, it would have no tendency to descend whatever. The adjustment is made between these limiting points: the worm-wheels are dragged by a simple friction apparatus, which can be regulated at pleasure by the handle, *f*. The spindle is raised by turning the wheel, *w*, and is balanced by the weighted lever attached to it at top.

The table which carries the work can be raised and lowered at will by the handle, *h*. This handle works an axle, upon which is a small pinion gearing into the wheel, *a*; and upon the same shaft with this wheel is a pinion which gears into the rack, *r*. The position is maintained by a ratchet-wheel and detent, until secured by the pinching-screws, *p p*. The table has a cross motion, and a circular one: the first is obtained by means of the screw, *s s*, which works in a fixed nut, and is revolved by a pair of metre wheels, commanded by the handle, *h'*. The circular motion is obtained by a worm-wheel and worm, worked by the handle, *h''*.

## APPARATUS FOR TESTING THE POWER OF PRIME MOVERS OF MACHINERY.

By James Whitelaw.

Fig. 1 is an elevation, and fig. 2 a plan, of an apparatus for testing the power of any prime mover of machinery. In the figures, the shaft or spindle of the machine to be tested is marked *a a*; and *b b b* is a spring fastened to a centre, which is keyed upon the spindle, *a a*. The lever, *c c*, turns loosely on the spindle, *a a*, and it is connected to the outer end of the spring, *b b b*, by the pin, *s*. *d* and *d* are plates connected to the levers, *c c*, by the pinching-screws, *e e*; these plates may be fastened on the levers at any suitable distance from the centre of the spindle, *a a*. The cylindrical part, *f*, is fixed to the levers, *c c*, and terminates in a spiral at its top end; and as the cranked end of the pin, *n*, rests on the

*Fig.* 1.

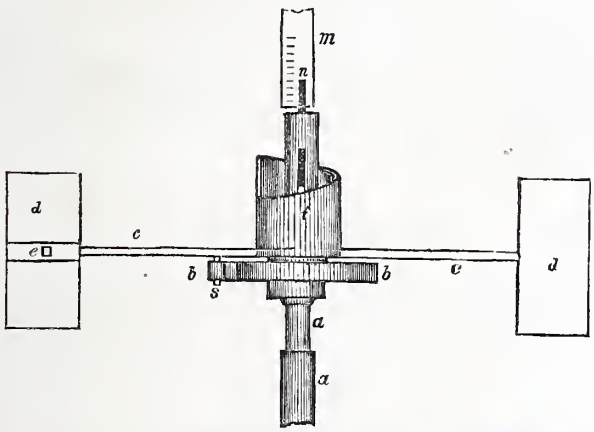
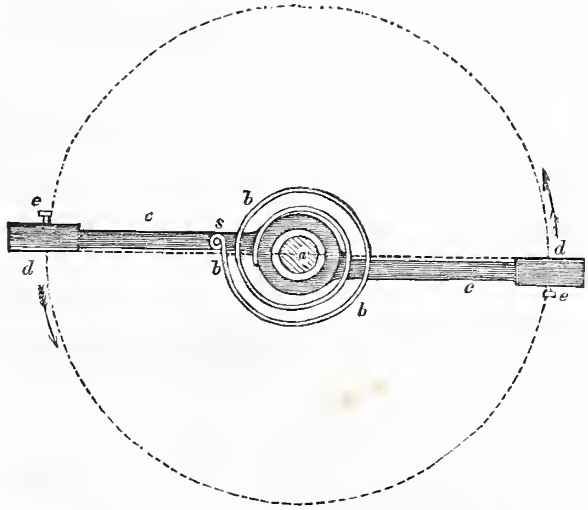



*Fig.* 2.




spiral, that pin will rise or fall according as the levers, *c c*, are turned in the one way or the other. The scale, *m*, is fixed to the framework which supports the spindle, *a a*.

The power of any machine experimented on is estimated by the distance that the pressure of the atmosphere against the blades, *d* and *d*, causes the lever, *c c*, to bend the spring, *b b b*; the distance that the spring is bent being a measure of the resistance on the blades, and consequently of the power of the prime mover. The arrangement of the parts is such, that the top end of the pin, *n*, will, if the scale, *m*, be properly graduated, point out the degree of pressure on the blades, *d* and *d*.

A very small apparatus will test a powerful machine, if the blades, *d* and *d*, be made to work in water instead of air.

The spring, *b b b*, should work inside of a circular box, like that which holds the spring of a common watch.

## GALVANIC BATTERIES.

### CHAPTER III.

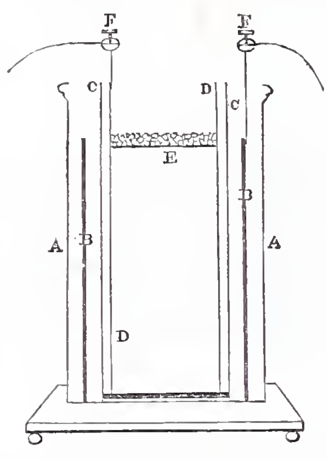
Before introducing to the notice of our readers some recent discoveries in voltaic combinations, we must correct an error into which we inadvertently fell, in the description of Professor Daniell's Battery in a former number. In that description, Daniell's is denominated the "*Sustaining*" instead of the "*Constant*" Battery; the Sustaining Battery, which we are now about to describe, being the invention of Mr Mullins, M.A., and late M.P. for Kerry, and brought forward in the year 1836, about the same time as Daniell's. This combination, with the inventor's recent improvements, stands deservedly high in the estimation of scientific men, being extremely simple and economical in its construction and employment, therefore a detailed description may not be inapposite; the more particularly, as many have ignorantly confounded it with Daniell's invention, supposing the principles of its construction to be similar; and here it may be well *en passant* to state, that, by reference to the *Annales de Chimie et de Physique, tome* 41, it will be found that the celebrated M. Becquerel, of Paris, discovered and made public, in the year 1829, the possibility of forming a constant voltaic combination, and actually constructed and described a Battery, in which he employed two liquids—one a solution of a salt of copper in contact with the copper, the other diluted sulphuric acid, or sulphate of zinc in contact with the zinc—a membraneous diaphragm (*baudruche*) being interposed. Having thus done an act of justice to a distinguished foreigner, by awarding to him the merit of being the first promulgator of an arrangement of voltaic elements capable of producing constancy of effect, we shall now proceed to describe Mr Mullin's invention, and show that it differs very materially from Daniell's in the principles of its construction, agreeing only with Becquerel's and it in the general principle of the employment of two electrolytes and a diaphragm. In order that our readers may more clearly comprehend the difference we have alluded to, we may premise that Mr Daniell states his Constant Battery to be constructed "on the principle of a central disposition of the active metal with regard to the conducting surface;"* and he carries out this principle in his Battery by the employment of a *rod* of cast zinc,

* See his 'Chemical Philosophy,' sec. 737.

*amalgamated*, and suspended in the *centre* of a circle of copper —the latter metal being one inch and a half distant from the former; which, the Professor states, "experience has proved to be the most advantageous distance between the generating and conducting surface.' * Now, in the Sustaining Battery, these principles are opposed by the nature of the arrangement, in which there *cannot* be *central* action, the zinc surrounding the copper, and in which the metallic surfaces are no more than one-fourth or three-eighths of an inch asunder; thus obviating, as far as possible, that retardation which arises from the passage of the current through an *imperfect* conductor. Again, Mr Daniell recommends acidulated solutions in contact with the generating metal;† which metal he states it to be requisite to amalgamate, in order to avoid local action, whereas, in the Sustaining Battery, *no acids are used*. Solutions of alkaline salts, the muriate of ammonia, "par excellence," being employed as far preferable, the zinc is *not* amalgamated, there being no local action; and, in consequence of the chemical effects being different, the power of this Battery can be sustained or kept equal for months, if required.

Professor Daniell states another of his principles to be, that of perfectly preventing the mixture of the liquids on the opposite sides of the diaphragms employed, such mixture producing strong local action; whereas, in the Sustaining Battery, a diametrically opposite principle is supported by the encouragement of mixture within a certain limit, Mr Mullins stating that he finds it considerably increases the effects, arising, as it does, from the action of "endosmose," which, in his and M. Dutrochet's opinion, has most probably an electric origin.

Having thus briefly explained the principles of construction of the Sustaining Battery, and wherein it differs from the "Constant," it only remains to refer the reader to the annexed diagram—showing in section the arrangement of the combination:




A A, an earthenware pot—say six inches high, on a stand; B B, sheet zinc rolled into a cylindrical form—Mosselman's is recommended; C C, a diaphragm of prepared sycamore, turned to the thickness of $\frac{1}{16}$th of an inch; D D, a copper cylinder without bottom; E, a copper shelf for holding crystals of the sulphate or nitrate, communicating with the external surface of the copper by holes made on a level with its surface; F F, binding-screws for connecting the metals. Muriate of ammonia, in the proportion of half of the saturated solution and half water, is in connection with the zinc, and a saturated solution of sulphate of copper with the copper. A square form of this battery is much used for working electro-magnetic apparatus, and for galvano-plastic purposes—for which, from its continued equality of power, it is peculiarly adapted.

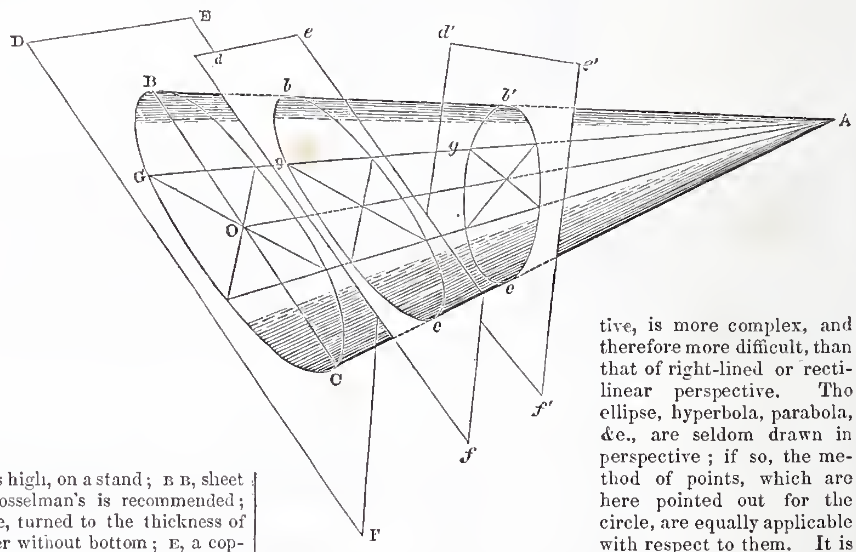
We now proceed to describe the recent voltaic invention of M. de Moleyns, M.A., F.G.S. This combination consists of an acidulated solution of nitrate of ammonia in contact with platina —a saturated solution of muriate of ammonia with rolled zinc— Mosselman's being preferred. The nitrate solution is separated from the muriate by a diaphragm of prepared wood, biscuit-ware, or other porous substance not acted on by the liquids. The acidulated solution is thus prepared:—Six ounces of nitrate of ammonia are dissolved in two fluid ounces of soft water, and this solution is then combined with an equal quantity, by measure, of the pure sulphuric acid of commerce; adding the acid gradually, and using a frigorific mixture, in order to prevent the heat evolved from exceeding 100° of Fahrenheit. The zinc is *not* amalgamated, there being no local action—a point of some importance, since it saves much trouble and expense. The inventor states that the use of the negative metal may be obviated by the employment of box, or other hard wood, cut to the thickness of veneer, and charred *superficially*. The whole combination is packed in a square glass or other vessel, the platina being in the centre, surrounded by the zinc, from which it is separated by the diaphragm. It is stated, that with enormous power this battery combines the advantage of freedom from the noxious exhalations, which make the employment of Groove's arrangement so dangerous—cheapness of the materials used— the possibility of preserving the action undiminished for any period required—and the very slight consumption of the positive metal in proportion to the power produced—arising from the absence of local action, and other causes, occasioned by the rather complicated play of chemical affinities in this peculiar combination. M. de Moleyns states, that this battery is particularly adapted for electro-magnetic developments, and that it possesses, in an extraordinary degree, the power of producing effects of intensity, as well as quantity, without any modification of the arrangement.

* See latter part of same sec.
† See his first Letter, Phil. Trans. for 1836

## LINEAR PERSPECTIVE.

### CHAPTER V.

1. The drawing of curves in perspective, or curvilinear perspective, is more complex, and therefore more difficult, than that of right-lined or rectilinear perspective. Tho ellipse, hyperbola, parabola, &c., are seldom drawn in perspective; if so, the method of points, which are here pointed out for the circle, are equally applicable with respect to them. It is evident, that if the eye be directly over the centre of a circle, or in a line drawn perpendicular to its plane from the centre, its perspective representation will also be a circle; for, if the plane of the picture be put betwixt the eye and the original circle, and of course parallel to it, and lines drawn from the eye to the circumference of the original, these lines would evidently trace out a circle on the plane of the picture.



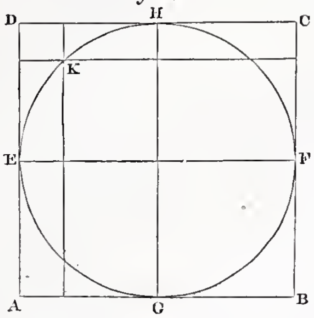

Let D E F be a plane on which there is the circle B G C, and O its centre, and O A, the principal visual ray, passing through tho eye A; now, if rays be supposed to pass from every point of the circumference to A, these rays will form a cone, and every plane, parallel to the original D E F, will be cut by these rays in a circle. If the plane $d\ e\ f$ be parallel to D E F, and which might represent the plane of the picture, it will be cut also in a circle as $b\ g\ e$: it will be greater or less than the original, according as it is farther off, or nearer to the eye than it—in mathematical language, the diameter of this circle is to the original in the ratio of their distances.

Now, suppose another plane, as $d'\ e'\ f'$, intersects the cone of

rays, but is not parallel to the original, it can be proved mathematically that $b' g' c'$, the perspective representation, will be an ellipse; it may be said the perspective of a circle is generally an ellipse.

If the eye of the observer be in the same plane with that of the circle, it will then appear as a straight line. A familiar example of this is seen by a tea-cup, which if a person hold in his hand, with the eye over the middle of it, it will then appear as a circle; and if it be gradually turned round, it will assume the forms of ellipses, becoming more and more elongated, until finally it appears as a straight line, or it will assume appearances of ellipses of every possible eccentricity, from zero, or the circle, to one of the diameters or the straight line.

*Fig. 2.*

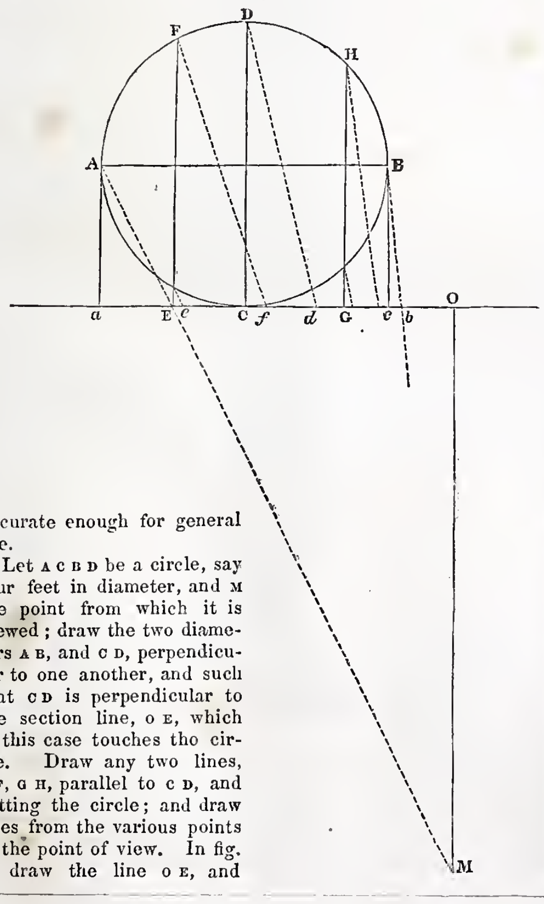



2. *To put a circle in perspective.*— Let E F G H be a circle; draw two perpendicular diameters, E F, G H, and tangents at their extremities; then A B C D, is a square.

If this square be put in perspective by the method previously pointed out, and the points F, G, H, E, found; there would then be four points given, through which the circle must pass. This way will do where great accuracy is not required, but the number of points may be increased. The point K may be taken in the curve, and through it parallels to the sides; the perspective of K may then be found, and also in the same way any number of points as may be thought necessary, and then the circle traced out with the hand.

The following way finds eight points which perhaps might be

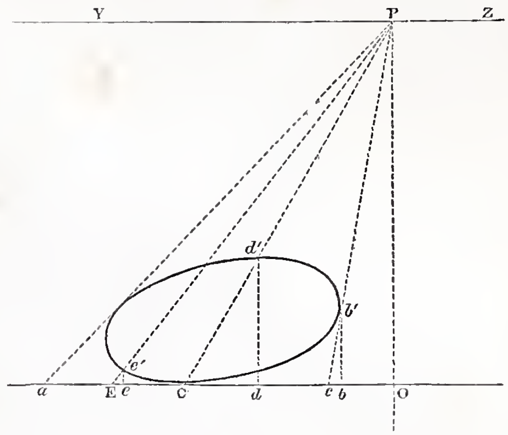
*Fig. 3.*




accurate enough for general use.

Let A C B D be a circle, say four feet in diameter, and M the point from which it is viewed; draw the two diameters A B, and C D, perpendicular to one another, and such that C D is perpendicular to the section line, O E, which in this case touches the circle. Draw any two lines, E F, G H, parallel to C D, and cutting the circle; and draw lines from the various points to the point of view. In fig. 4, draw the line O E, and parallel to it, Y Z, the horizontal line, and take into it P, the point

*Fig. 4.*



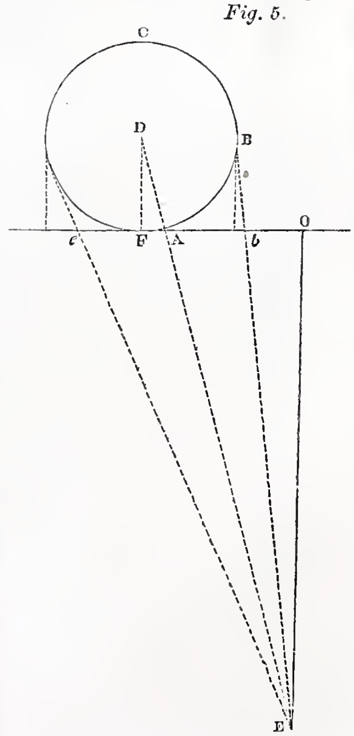

of sight; leave off O E, O C, &c., O $e$, O $d$, &c., equal to O E, O C, &c., and O $e$, O $d$, &c. in fig. 3.

Because E F, C D, are perpendicular to the section line in fig. 3; in fig. 4 they will run to the point of sight P, and then perpendiculars from $e$, $d$, &c., will meet these lines in points $e'$, $d'$, &c., which mark out points in the circumference of the circle; and with a steady hand the perspective of the circle may be traced out after the rest of the points have been found in the same manner.

3. On a former occasion, the method of putting any rectilinear figure into perspective was shown, and by the method of points, as applied to the circle, any curvilineal figure may also be put into it; and as all figures on the same plane, no matter how irregular they may be, are bounded by straight lines, or curves, (or the figure may be called *mixtilineal,*) it is evident that the methods for these two conjoined will be the modo of proceeding in general cases.

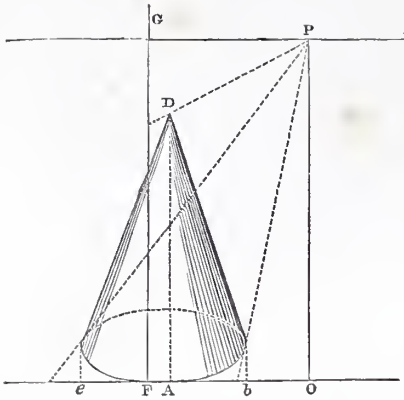
4. *To put a cone in perspective.*—Let A B C, fig. 5, be the plane of a cone three feet in diameter at base, and four feet high. Let F O be the section line, and E the point of view, eight feet from the cone; let D be the seat of the vertex; draw D F perpendicular, and draw the visual ray, E D.

*Fig. 5.*




In fig. 6, let Y Z be the horizontal line, P the point of sight, and O F the base line; the base of the cone being a circle, it must therefore be first put into perspective. 2. Make O F, O A, equal to O F, O A, in fig. 5, draw the perpendiculars F O, A D, and leave off the height of the cone on F O four feet, and from this point draw a line to P; then where it cuts perpendicular from A in D, D will be the vertex; then draw tangents from D to the curve — they will form slant sides of the cone. Or if O $e$, O $b$, be made equal to O $e$, O $b$, in fig. 5, and perpendiculars drawn, they will touch the curve in two points, to which, if lines be drawn from D, they will form the slant sides of the

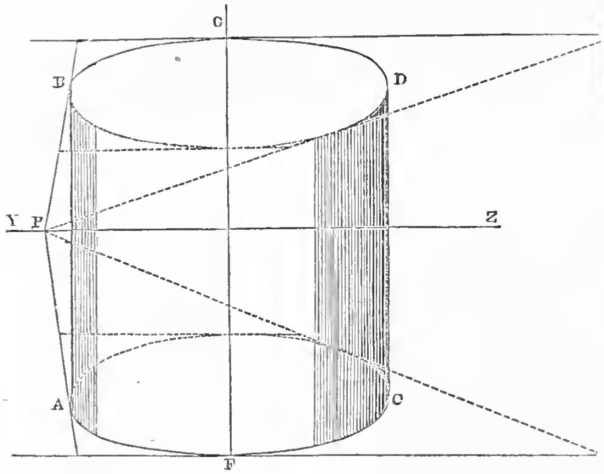
*Fig.* 6.




cone. In fig. 5, *e b* is the representation of the apparent size of the diameter of the circle, found by drawing lines to represent visual rays, to touch the circle.

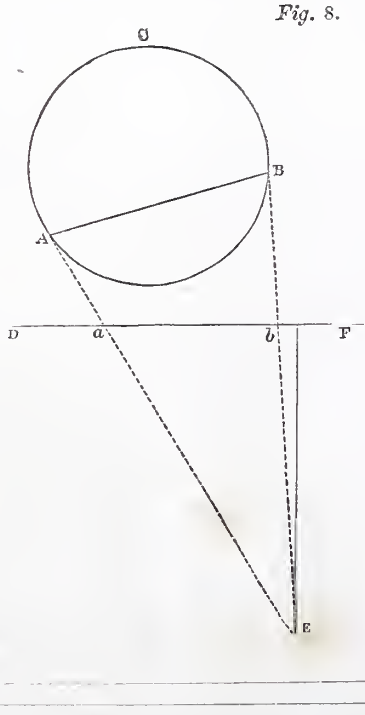
5. *To put a cylinder in perspective.*—The top and bottom are

*Fig.* 7.




equal circles; the bottom circle can first be put into perspective, and then the top one directly over it. The plane of the picture touches the cylinder; F G is the line on which the height is laid off; Y Z is the horizontal line, and P the point of sight, as before. The two lines, A B and C D, may be made to touch the circles in A, B, and C, D; or these points may be found by the method shown in tho last example.

*Fig.* 8.



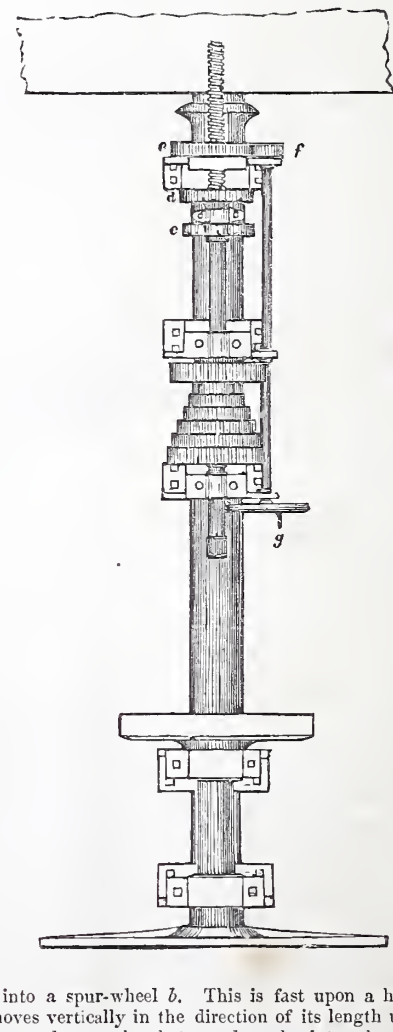

6. *To put a globe in perspective.*—If the plane of the picture be perpendicular to the visual ray, passing to the centre of the sphere, the representation will be a circle; but if it be not perpendicular, the representation will be an ellipse. Let A D O be the plane of the sphere, E the point of view, and D F the section line. Now, if lines be drawn from E to touch the sphere in A and B, A B will be the apparent size of the diameter, and *a b* its representation. A section of the sphere through A B will be a small circle of the sphere, of which A B is the diameter; and all the visual rays from E to touch the sphere, will touch the circumference of this circle. The perspective of the globe will then be found by putting this circle into perspective by the method previously shown.

## VERTICAL DRILLING AND BORING MACHINE.

By Messrs. Randolph, Elliot, & Co.

This machine, of which the drawings show a front and side elevation, consists of an upright pillar of cast-iron, to which the working parts are attached by a series of brackets in the ordinary way. The spindle is wrought by a cone either directly or through double gearing, in every respect similar to the back-speed of a lathe. The self-acting feeding motion of the spindle is a train consisting of a pinion *a*, fastened on the top of the spindle, and

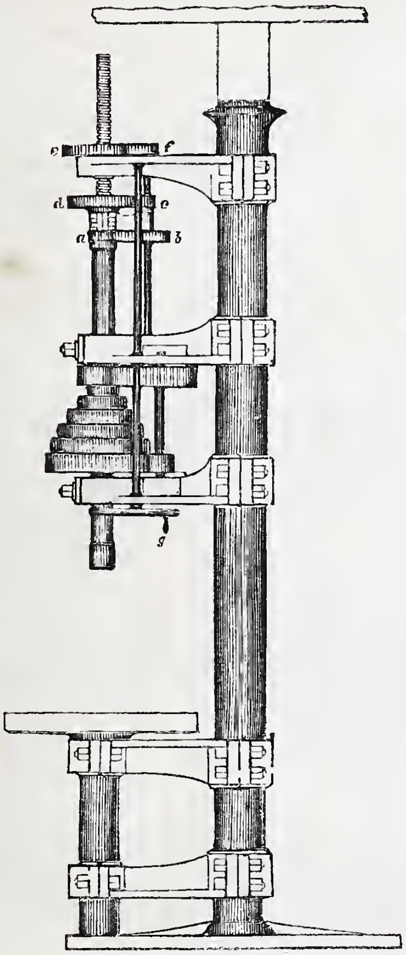
*Fig.* 1.—*Front Elevation.*




gearing into a spur-wheel *b*. This is fast upon a hollow spindle, which moves vertically in the direction of its length upon the stay-bar between the two brackets, and works into a brass link which serves to connect the top of the boring spindle with the bottom end of the screw, and by its motion upon the stay-bar keeps the feeding motion in position. Upon the upper end of the same

hollow spindle, is the pinion, *c*, which gears into the wheel, *d*, attached to the bottom end of the screw by means of claw catches, in this way communicating a slow feeding motion to the boring spindle. Besides this self-acting feed-motion, the spindle may either be elevated or depressed by means of the wheel and pinion, *e* and *f*, which are worked by the hand-wheel, *g*. The wheel, *e*, is fast upon the

*Fig. 2.—Side Elevation.*

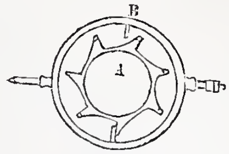



nut, which revolves independently of the screw in the upper bracket. By this combination, the self-acting feed-motion is produced by the turning of the screw, and the hand-feed motion by the turning of the nut. Both feed-motions may thus be in action at the same time, the hand-motion elevating and bringing the drill into position, without reference to the motion of the self-acting feed.

## HALL'S ASTRONOMICAL AND METEOROLOGICAL CLOCK.

The meteorological apparatus of this clock, which was exhibited at the Crystal Palace, in Class X., No. 60, is founded on a very beautiful principle, and is worthy to be termed a new and important discovery, in the highest sense of the term. There is no principle involved in it which has not been known to the scientific world for many years, but it involves a most striking and ingenious application of principles already known to an object of the very highest importance, namely, the correct registration of meteorological phenomena. These have hitherto baffled all attempts to record them with certainty and precision, for any considerable length of time, without the necessity of constant attendance and observation. The greatest or least pressure of the atmosphere, the highest or lowest temperature for any one night, or even for any given time, may easily be made to record themselves on self-registering instruments already in general use. But it was still a desideratum, and one which the most sanguine meteorologist had probably despaired of attaining, to invent an instrument which would record with precision, and with perfect accuracy, for any desirable length of time, every slight variation, however minute—every oscillation, as it were—in the weight or temperature of the air. This is accomplished by the clock invented by Mr. G. F. Hall of Norfolk Street, Fitzroy Square, the inventor of the patent diplometer for railway purposes, and various ingenious improvements in philosophical instruments.

Fig. 1.




Automaton-registration, founded on correct principles, appears to be the only key to meteorological discovery. The phenomena observed must be numerous, simultaneous, and general. This fact has been long recognized, and even to some extent acted upon for more than a century. Meteorological observations, indicating the state of the wind, the temperature and pressure of the atmosphere, and latterly, in some cases, the motions of the magnetic needle, have been kept at different places, with probably little useful result. Though kept with considerable care and perseverance, there has been a want of that continuous attention and that uniformity of action, which can alone lead to important discoveries in the laws which regulate the ebbing and flowing of the atmospheric ocean. Now that we are rapidly girdling the earth with the telegraph wire, and teaching electricity to carry our messages to and fro with an instantaneous movement, we may perhaps succeed in making use of this subtle agent to reveal his own laws, and in forcing him to carry the tidings of his own secrets. There is no doubt that most of the atmospheric changes which hourly occur around us are due to the invisible agency of this remarkable element; and when there is established over the face of the earth—as probably there will be at no distant time—a complete system of electro-magnetic communication, this may easily be rendered instrumental in ascertaining the general laws which regulate the atmospheric phenomena.

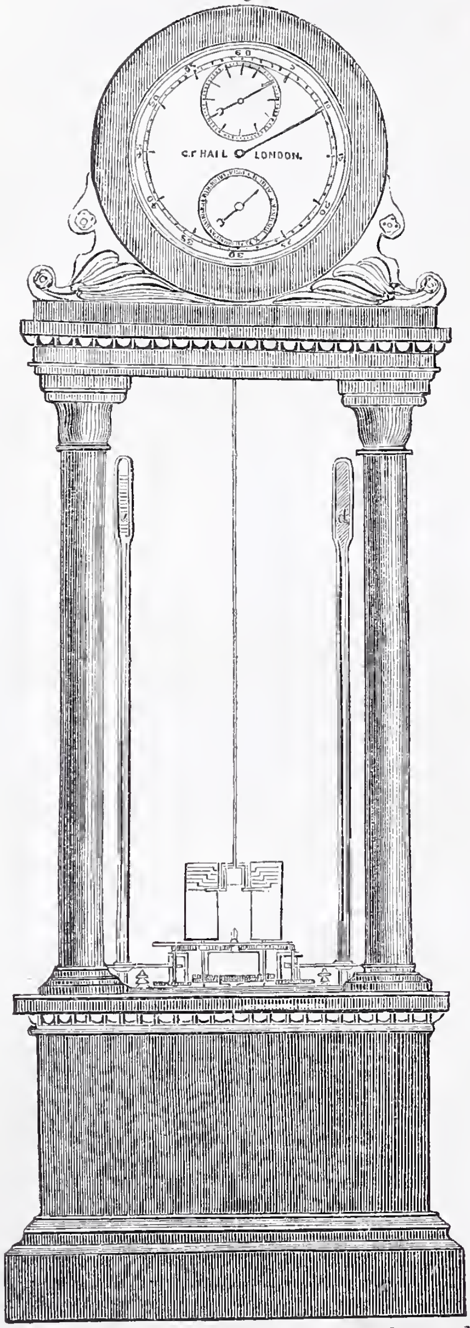
Fig. 2.

Mr. Hall's astronomical and meteorological clock is perfectly applicable to the registration of barometrical and thermometrical indications at any distance. The clock may be stationed at London, and register correctly the temperature or pressure of the atmosphere in any part of the world—at the top of the highest mountain, or the bottom of the deepest mine—provided a connecting wire can be carried to the place of observation. The means of registration is simply by clockwork, employed to communicate a vibratory motion to the instruments which furnish the indications, and then again to register these indications on cylinders caused to revolve by the horological mechanism.

Before proceeding to detail the precise manner in which the results are produced, to which we have thus adverted in general terms, we may state that the invention is more fully described as "an improved astronomical and meteorological clock, intended to give a more correct measure of mean time, and to register the mean hourly variation of the barometer and thermometer." The escapement of the clock is a new vertical dead-beat escapement, and the pendulum is furnished with a new micrometrical adjustment for temperature. The details will be understood by reference to the annexed diagrams.

Fig. 1 represents the 'scapement of the clock, about half-size, the reaction being on a point, instead of two bearings as usual. A, is a vertical wheel of seven teeth, which move in a horizontal plane; B is a concentric circle, with two ruby pins moving in a vertical plane. The pins being circular, or chamfered, the action is dead during the coincidence of the two planes; but a vibratory motion being communicated to the pins, the top of the teeth strike, escape, and slide under them, giving the necessary impulse to the pendulum.

Fig. 3.




The pendulum, fig. 2, is furnished, as already stated, with a micrometrical adjustment for temperature. This is effected by a compound rod of brass and zinc—metals of greatly unequal expansion—in the proportion of twenty brass and ten zinc, joined immediately above the bob. The shaft of the pendulum consists of two glass tubes, the one inserted into the other. The bob is placed upon studs fastened to the inner glass tube, and passing through the outer. The tubes expand downwards, and the compound compensating bar upwards. The latter is indicated in the drawing by the black line, and the two exterior lines are the glass tubes. The brass part of the compensating-rod is also tubular, enclosing a cylinder of zinc; a zinc screw is soldered into the top of the brass tube, and a steel screw into the zinc cylinder, both of the same pitch. The length of the compensating-rod is first obtained, as nearly as possible, by calculation; then if the pendulum is found to be compensated too much, the rod is turned to the right, which shortens the zinc screw and increases the steel; the difference between the expansion of zinc and steel being the amount rendered minus in the compensation—that is to say, it is reduced by the amount of that difference. If, on the other hand, the pendulum is not sufficiently compensated, the rod is turned to the left, which produces an opposite effect, and the difference of expansion between the metals is the quantity now rendered plus, or this difference is added to the amount of compensation.

Fig. 3 is the elevation of the clock, about one-eighth of the size of that which was placed in the Exhibition, showing the most curious part of the machine, the meteorological registering apparatus. To render this intelligible to the general reader, we may state that, if a rod of wood or metal be vertically suspended from about the middle, and a weight similar to that of a pendulum be affixed to the lower end of it, the vibrations of the rod will be slower in proportion to the increase of weight affixed to the upper end, or upper half of the rod, and a very small weight, so affixed, will produce a considerable diminution in the number of vibrations per hour. The effect is the same as if the weight, or bob, attached to the lower end were diminished, because, in the vibrations of the rod, from any point of suspension near the middle, the upper and lower portions tend to balance each other. The difference is caused by the variation in the radius of gyration—the centre of gyration being that point, where, if all the matter of a body were concentrated, a given force, impressed at a given distance from the axis, would produce the same angular velocity, or, in other words, the same rate of vibration as it does with the matter in its natural form. Now, let us suppose that, instead of a simple rod and weight, a barometer is thus suspended, and made to vibrate continually on knife-edges from some point about the centre, we shall find that, for every variation in the rise or fall of the mercury, the centre of gyration will vary, and a corresponding difference will ensue in the number of vibrations made by the suspended barometer in any given time, say in one hour. The same effect will be produced on the thermometer, which, by using a liquid very susceptible of expansion, can thus be made to indicate, by the variation in the number of its vibrations per hour, the smallest changes of temperature.

We are now in a position to understand the mechanism. A, *a*, fig. 3, are two revolving cylinders, fastened to the arbors of the first wheels of the train, and which revolve, upon the average, once in three hours. B, *b*, are the escape-wheels of the train, of the same kind as the clock (the vertical dead-beat), of twenty-five teeth. C, is the going-barrel, to impel the two independent trains. D, *d*, are the barometer and thermometer. E, is the rod, to which is fixed the marking apparatus in connection with the revolving cylinders, A, *a*. The action of this entirely new invention will now be obvious:—The escape-wheels, B, *b*, communicate in their revolution a constant vibratory motion to the barometer and thermometer, D, *d*; the radii of their gyrations, as inverted pendulums, being continually affected, either by the pressure of the atmosphere in the one, or by the changes of temperature in the other. For example, D, the Torricellian barometer, will, if the mercury fall one inch, increase the number of its vibrations per hour 1,000, every one of which is registered on the revolving cylinder, A, which gives a line corresponding in length to the number of vibrations made by the barometer per hour. The effect produced on the thermometer, *d*, by any change of temperature is precisely similar, and its variation per hour is registered on the cylinder, *a*. The hourly measure is marked by a break in

the lines, which is effected by the escape of a wheel, causing the descent of the rod, E, with its attached marking apparatus, one-twentieth of an inch.

It will now be evident that, by this arrangement, the barometer, D, and the thermometer, *d*, or, as they are termed by the inventor when used in this system, the baro-gymeter and the thermo-gymeter, instead of being attached to the horological apparatus, or what is termed the gyrometer, may be removed to any distance from it—to the summit of any mountain, or to any other remote place of observation, at even a thousand miles' distance—provided the electric wire, with a make and break contact, be used as the means of communication, for keeping the vibratory motion in constant action. Perhaps, therefore, the time is not far distant when this clock will be a part of the common furniture of numerous telegraphic establishments, communicating with all parts of the world.

## THE SELF-CLEANSING TUBULAR FILTER.

In proportion to the value of perfectly pure water, a good and convenient filter is an object of very great importance, and we are disposed to believe that Mr. Murray's "self-cleansing tubular filter" (registered April 8, 1850,) offers several very considerable advantages which ought to recommend it to more general attention. The pure-water question is now a subject of all-engrossing interest in most of our large towns. In some of them the supply is good, and the water seldom requires the use of a filter; but these, we regret to say, are exceptional cases. Manchester is now well supplied with pure water; but even in Glasgow, where there is likewise a tolerably abundant supply, the purity of the water, which, for the greater part of the city, is drawn from the Clyde, depends to a great extent on the state of the weather. After heavy rains, the filtering to which it is subjected before being carried into the city, is found to leave it in a very unsatisfactory state for culinary purposes; and therefore in Glasgow, as in other places, even where the supply of water is generally good, the occasional use of a filter is indispensable.

The common filtering medium now used, is composition porous stone, differently prepared, and differently applied. By such filters clear water is obtained, and in a sufficient stream for a time, but the stone soon becomes choked by use, and cannot be properly cleansed; the case must therefore be fitted with a new filtering medium, which is nearly as costly as an entirely new filter. There is no method in general use of thoroughly and frequently cleansing the medium, whether it consist of porous stone, or of some other substance, and therefore the common filters are not only expensive at first, but become in a short time inefficient in their action.

Mr. Murray's tubular filter is not only the cheapest that has yet been laid before the public, but appears to be in many respects the best. It acts with perfect efficiency, and is easily cleaned. Fig. 1 is an elevation of this apparatus in a complete state, and fig. 2 a longitudinal section.

It consists internally of a metal tube, copper being preferred by the patentee, although we are inclined to think that tinned iron-plate, or some composition metal, would be better. This

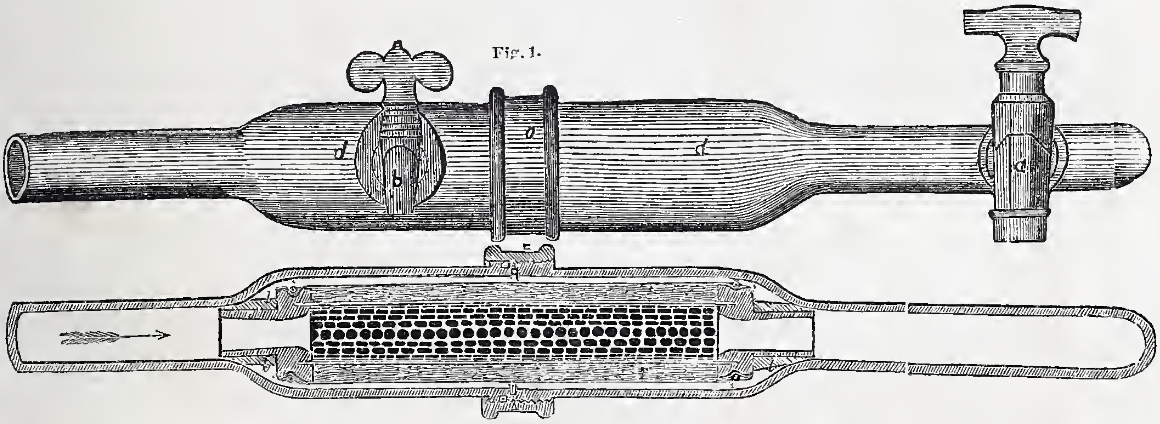



Fig. 2.

tube is perforated, as shown in fig. 2, and is covered with several layers of flannel and calico, F, the former being placed next the tube. The ends of this perforated tube are inserted in metal rings, at S S, and the extremities of the calico are firmly secured round the rings, forming a water-tight fastening. The flannel and calico are, in this arrangement, the filtering medium, instead of the porous stone in common use. The metal rings are partly covered with a conical leather washer, *l l*, which farther insures a water-tight joint between the dirty and the filtered water. This very simple arrangement, enclosed in the outer case, D D, (fig. 1,) constitutes the whole of the tubular filtering apparatus.

The method of applying this filter is likewise claimed by the inventor as an important improvement. It consists in attaching it to the service-pipe, between the cistern and the tap, thus bringing to bear upon it the pressure of the column of water from the cistern. To admit of the apparatus being thus attached, and taken out and cleansed, the outer case, D D, is formed in halves, the one half to the left being attached to the service-pipe, A, from the cistern; the other having a short service-pipe, *e*, (fig. 2) fitted with the tap, A, (fig. 1.) The filtering tubes are put into one half, and the other part is brought up and screwed in, as shown at E. The water, flowing in the direction of the arrow, percolates through the flannel and calico into the space, *b b*, whence it is drawn off, perfectly filtered, by the lesser tap, B, and the water for common household purposes is drawn from the larger tap, A, after having rushed through the perforated tube, without passing through the filtering medium at all. In this process, however, the water which is drawn off in large quantities for common use by the tap, A, effectually cleanses the filter from its impurities, and this, after long use, may be still more efficiently done, if required, by taking the apparatus to pieces.

"This," says the inventor, "is the first instance of the pressure from the column of water being made use of; and another advantage derived from it, besides the thorough cleansing of the filter, is, that it keeps up a large and rapid stream of pure water. The position of this apparatus renders it exceedingly convenient, obviating the trouble of refilling it, as in others."

There is no doubt that the pressure from the cistern must keep up a copious stream of filtered water, and must at the same time operate powerfully in cleansing the filtering medium when the tap, A, is opened. The chief advantages claimed by the author for his invention, are "its cheapness, its lasting efficacy, its convenient position, and the continued, full stream of pure water obtained from it."

# HISTORY.

## CHAPTER X.

### PERSIAN MONARCHY—EGYPT.

By Cæsar's usurpation of sovereign power, and by the successful efforts of his successors to retain that power, Rome was brought more on a level with the provinces. The Roman citizens, subjected to the yoke of an emperor, were no longer the masters of the provinces; they were only the fellow-subjects of the provincials. A monarchial government over so wide an empire produced its natural effects; it introduced a certain uniformity of character throughout the whole of its territories. If the governors appointed by the emperor, or his slaves in the senate, familiarized the provincials with Roman forms of civil polity, he and the Romans who accompanied him ingrafted the habits, and inclinations, and opinions of those among whom they lived, upon their original stock—just as our civil and military servants of the India Company do at the present day—and returned thus sophisticated to Rome, to make their fellow-citizens like themselves. In order to have some conception of the manner in which the old Roman character was modified under the empire—in order to know what the Roman citizens became under the imperial sway—it is necessary to view more in detail the character of the people with whom the Romans were thus brought into contact. For our purpose, it will suffice to restrict our attention to those countries in which the population was of Greek origin, or in which the Greek race held sovereign sway up to the moment of the Roman conquest.

This tract of country embraces Greece proper, Thrace, the coasts of the Black Sea, Asia Minor, Asia bounded by Mount Taurus, the Oxus, the Indus, the Indian Ocean, the Arabian Gulf, and the eastern extremity of the Mediterranean, Egypt and Cyrene in Africa. All this immense space was either inhabited by Greeks, or by people governed by Greeks, or by a government organized by Greeks. The influence of Greek civilization, of Greek literature, arts, arms, and civil polity, was felt and seen throughout its whole extent. But before we speak of Greek civilization and its influence, it will be necessary to glean such information as has come down to us, of the earlier history of these provinces in which the Grecian had been ingrafted upon an older civilization. The sceptre over the whole of these lands was transmitted to the Greeks from the Persians; and, therefore, to the Persian monarchy our attention must, in the first instance, be directed.

Our knowledge of the ancient Persians is derived exclusively from foreign authors. Anquetil du Perron has introduced to European knowledge a valuable monument of Persian history; but it relates to an age much posterior to that of which I am now speaking. The Zend Avesta is the collection of religious books in the possession of the Parsees, the genuine expatriated descendants of the Persians. These books are of great antiquity, and in dialects now obsolete, the Zend and Peblui. They are, however, but fragmentary relics of an older system expressed in the language of the age in which they were gathered together. It is clear, from many authentic sources, that after the overthrow of the Persian dynasty by Alexander, a number of minor monarchies were organized throughout its domains; in all of which Greek laws and worship maintained the ascendancy. The Syrian Greek sovereigns extended their sway over the greater part of Persia; the rest was subjected by the Greek Bactrian kings. The Arsacidæ, a native race who succeeded the Greek rulers over western Persia, conformed to Greek usages. It was the Sassanides—the Parthian sovereigns of later Roman history—who restored the national worship and laws. We know, from contemporary Greek historians, that this dynasty sought to restore in everything the old Persian laws, institutions, and religion, which had, in state affairs at least, been superseded by the Greek. The recovery of the Zend Avesta, with a grammar and dictionary of the language in which it is written, have enabled that eminent oriental scholar, Sylvestre de Say, to decipher imperfect inscriptions found in various parts of Persia; all of which he has found to relate to monarchs of the Sassanian dynasty, and all of which are couched in a dialect clearly approximating that which we find in the Zend Avesta. We know what an alteration a few centuries have made in the English language; how much more rapidly must this gradual change be effected in a language not fixed by a written literature. The close approximation of the language in these inscriptions to the language in the Zend Avesta, fixes the age of the latter. This inference is confirmed by the nature of the collection. It consists of fragments patched together with little skill, sometimes in the most mechanical manner. It is the relics of a former, and, for a time, forgotten age, remoulded into a whole; there are huge omissions that cannot be supplied; there are surreptitiously admitted pieces evidently of foreign origin. This patchwork served to gratify the people, in whose affections and imaginations some chaotic reminiscences of the old religion still lived glimmeringly on; it revived and invigorated a national spirit—and that was all the compilers wished. But it lends only a feeble and imperfect aid to the historian. He dares only draw upon it with a timid hand for illustration—for corroboration of what is doubtful it furnishes him with no facts.

It is still from foreign writers—Greek and Hebrew—and from the monumental records lately discovered, that we learn what we know of the facts of old Persian history; and what we learn from these sources is scanty enough.

There appear to have been two great states which grew up to maturity about the same time, in the countries adjoining the Euphrates and Tigris—the Assyrians, whose capital was Nineveh, and the Babylonians. Our information regarding these two states is not sufficiently accurate to enable us to decide whether they were aggregates of various races, or tribes of one race. It is certain that the Babylonians were so called from their metropolis; and that city being occasionally designated the head of the Chaldeans, it is possible that the majority, at least of its citizens and subjects, may have been of that fierce warrior race, which inhabited at one time from the mountains of Armenia to the embouchure of the united Tigris and Euphrates, spreading occasionally its devastating hordes over Syria, Palestine, and Phenicia; and the broken remnants of which are still to be found in scattered villages between the ruins of Nineveh and the Armenian mountains. Two circumstances combine to lead us to the inference that the Assyrians were a different race. It appears, from the Hebrew annals, that the Assyrian monarch conquered Babylon a short time before the captivity of Israel. We find in the Hebrew books mention made of Chaldeans as a peculiar body of diviners at his court. We find Herodotus, at a much more recent period, giving the designation *Chaldeans* to the attendants in the temple of Belus, or Baal, at Babylon. This notice of the Chaldeans as a people apart, and the connexion of them with the worship indigenous in Babylon, leads us to infer the possibility that the Assyrians were a separate race from the Chaldeans; an inference corroborated by a passage in the Second Book of Kings, from which we learn that the national god of the Assyrians was called Nisroch. It is still, however, possible that Babylonians and Assyrians may have been two sections of the same race. We find in the Hebrew writings, the leaders of the Jews, when they wished to conceal the threatening message of Salmanasar the Assyrian king from their followers, requesting his messenger Rabshakeh to use the dialect of Aram and the Babylonian,—the Chaldean tongue was an Aramitic dialect of the Semitic tongues. It is possible that as Babylonian from Babylon, so Assyrian may have been derived from Assur, a city of which some vague traces remain in history, and may have merely designated those Chaldean tribes inhabiting Assur, and subject to its sovereign. All that we can say, with any degree of certainty, is, that some time before the overthrow of Jerusalem by the generals of Nebuchadnezzar, the plains and hills between the Tigris and the Euphrates, and the southern and western slope of the mountains eastward of the former river, were the scene of the struggles for ascendancy between the Assyrian and Babylonian powers, which terminated in the subjection of the latter; and that Nineveh was the capital of the former, Babylon of the latter power.

There is no doubt that Babylon was built before Nineveh. The sacred historian, Josephus, ascribes the erection of the Tower of Babel to Nimrod, and this tower was the commencement of the future city. He ascribes to Nimrod, also, the honour of founding Nineveh; but this is a point on which the evidence of history is uncertain. Ninus, a descendant of Nimrod, married the famous Semiramis, who first established the Assyrian empire on a great and solid foundation, and Nineveh was probably at this time the capital of that empire. Semiramis, however, enlarged and adorned Babylon, until it became a truly magnificent city. For this purpose, she is said to have collected, from all the provinces of her vast

empire, no less than two millions of men, whom she employed in the gigantic undertaking for several years. The city was erected in the middle of the extensive plain of Shinar, and occupied both sides of the Euphrates. It was surrounded with walls which, according to Herodotus, were eighty-seven feet in thickness, three hundred and

SUPPOSED WALLS OF BABYLON—*from an ancient coin.*

fifty feet in height, and four hundred and eighty furlongs, or sixty miles, in circuit. These walls were built of brick, cemented with bitumen, and encompassed the city in the form of a square, each side of which was fifteen miles in length. The river ran through the city from north to south, and on each side was a quay of the same thickness as the walls of the city. In these there were one hundred gates of solid brass, twenty-five in every side of the square, and from all the gates proceeded streets in straight lines, each being fifteen miles in length, and crossing each other at right angles. On the eastern side of the river was the ancient palace, which was thirty furlongs, or three miles and three-quarters, in the circuit of its walls; and on the opposite or western side of the river was another palace, the circuit of which, with its enclosed grounds, was seven miles and a half. In the middle of the city, Semiramis erected a lofty temple in honour of Belus, which stood near the ancient palace; and rising from this temple was a tower of gigantic magnitude, celebrated in ancient history. The hanging gardens, so often mentioned with admiration by the Greeks. were attached to the western palace at a subsequent period.

Her other city of Nineveh was not less imposing in its proportions, and in the magnificence of its buildings. According to Diodorus Siculus, Nineveh was the largest city in the world. It was built in the form of a parallelogram, its longer sides being thirty-six miles in length, and its shorter about twenty-four. The walls of this royal capital were a hundred feet high, and so broad as to admit of three chariots being driven abreast. They were fortified with 1,500 towers, all of them 200 feet in height. The city, though so vast in extent, is estimated to have contained not much more than half a million of inhabitants; the houses were scattered, or thinly planted, as in our suburban districts, and within the civic territory, all over its vast expanse, and blending with the city itself, were gardens, parks, vineyards, orchards, corn-fields, and royal demesnes. It is estimated that the area of Babylon was 225 square miles, that of Nineveh 216 square miles, while that of London and its environs is only 114 square miles; so that, with an area of little more than half that of Nineveh, the population of London is nearly four times greater. In addition, however, to the great extent of open space within the ancient oriental cities, it may be remarked that the majority of the houses contained only one story, so that the people were spread over a much wider area than in our western towns.

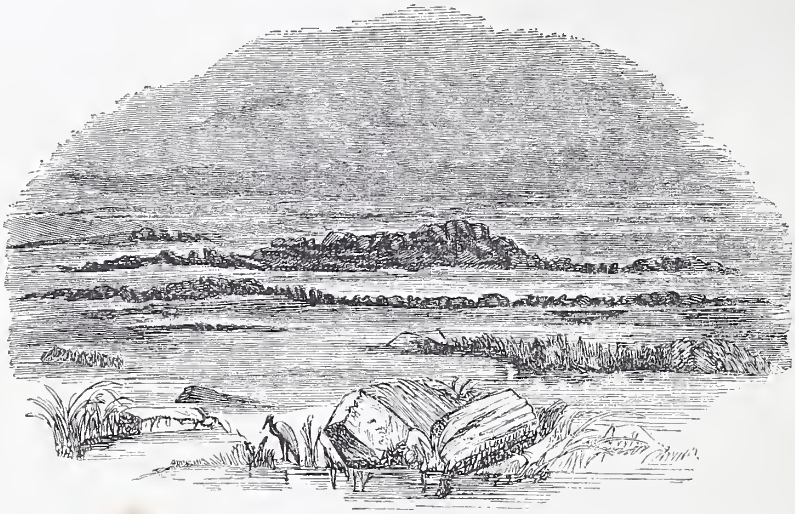
These two cities continued, under one imperial government, to constitute the twin-capitals of Assyria for several centuries. Semiramis, after enlarging Babylon, thirsted for the glory of conquest, and, assembling a numerous army, she marched through Medea into Persia; then passed into Egypt and Ethiopia; and, finally, after a career of great glory, carried her arms against the Indian nations, by whom she was signally defeated, and soon afterwards died. Her son, Ninyas, succeeded her in the empire, but little is known of his reign, or of that of his successors, for the long period of twelve hundred years, during which the history of Assyria is almost an utter blank. This period embraces about thirty reigns, and the last of the monarchs in the series was Sardanapalus, celebrated only for his indolence, effeminacy, and voluptuous luxury. In the reign of this prince occurred the revolt of the Medes, which resulted in the fall of the first empire. Of this event we have two accounts, by Greek authors—Ctesias and Herodotus—differing considerably from each other. According to Ctesias, the revolt was made by Arbaces, a Mede, "a valiant and prudent man," says the historian, "and general of the forces who were sent every year out of Medea to Nineveh." This man was stirred up by Belesis, the governor of Babylon, to overthrow the Assyrian empire. Arbaces prevailed on the Medes and Persians to invade Assyria, and Belesis persuaded the Babylonians to aim at their independence by joining in the ambitious enterprise. Sardanapalus, when he heard of the revolt, appears to have at first displayed considerable energy; he led forth the forces of the other provinces against the rebels, and twice defeated them in battle, with great slaughter. This success led to induce security on the part of the monarch; and while he was rejoicing at his victories, and feasting his army, Arbaces induced the Bactrians to revolt, and suddenly attacked the royal camp, in which he made a great slaughter of some, and forced the rest into the city. Sardanapalus then committed the charge of the army to Salamenes, the queen's brother, and took upon himself the defence of his capital. But the tide of battle was now turned against him; his forces were twice defeated by the rebels, and this success of the enemy encouraged the revolt of other provinces. The city, however, was strongly protected, and the king, having made extensive preparations for enduring a siege, continued to hold out, encouraged by an ancient prophecy, "that Nineveh could never be taken by force until the river became the city's enemy." For two years the siege continued; but it happened that, on the third year, the Tigris, swollen by incessant rains, overflowed its banks, inundated a part of the city, and swept away twenty furlongs in length of the lofty and massive wall, which had hitherto resisted all the attacks of the besiegers. The king, conceiving that the oracle was thus accomplished, and the doom of Nineveh sealed, sullenly resigned himself to his fate; but that he might not fall into the hands of the enemy, he caused an enormous pile of wood to be erected in his palace court, on which he heaped together all his treasures—his gold, silver, and royal apparel—and enclosing his eunuchs and concubines in an apartment within the pile, he caused it to be set on fire, and miserably perished in the flames, with all the objects of his guilty and sensual attachments during an inglorious reign. The revolters, hearing of this catastrophe, entered through the breach which the river had made in the walls, took the city, and proclaimed Arbaces king.

In this account, which is quoted from the history of Ctesias by Diodorus, there seems to be a large admixture of fable; but the general character of Sardanapalus, the fact of his defeat and death, the capture of Nineveh by the revolted Medes, and the elevation of their leader, Arbaces, to the supreme power in that city and the adjoining country, may be received as well attested facts of history. The account given by Herodotus, relates to another Medean of the name of Dreoces, who, about a century afterwards, gathered sufficient strength to make a second revolt, and to overthrow the elder race of his victorious countrymen.

This was the end of the first great Assyrian empire, and of the pride of Nineveh as its capital. Out of the ruins of this empire sprang three kingdoms—the kingdom of Medea, the kingdom of Babylon, and the kingdom of Nineveh. Belesis reigned in Babylon, and Arbaces in Nineveh; and during the existence of the dynasties founded by these usurpers, the two kingdoms were engaged in frequent rivalry. Belesis, who reigned in Babylon, B.C. 747, is the same with Nabonassar, and was succeeded by his son, Merodach-baladan. Sennacherib, one of the descendants of Arbaces, came to the throne of Nineveh, B.C. 717, and extended his conquests westward to Palestine. His son, Esarhaddon, added Babylon to his father's conquests, and thus were the two great cities again united for a period under the same sceptre. Esarhaddon, after reigning thirty-nine years with great glory, was succeeded by his son, Saorsduchirus; and after this prince reigned Chyniladan, who was succeeded by Saracus, B.C. 648. It was under Saracus that Nineveh was taken and utterly destroyed by Cyaxares, king of the Medes, assisted by Labynitus, king of Babylon, who is presumed to have been the same as Nabopolassar.

Thus utterly perished the great city of Nineveh, upwards of six centuries before the advent of Christ, after having flourished as the capital of the Assyrian empire, and the residence of mighty kings and conquerors for nearly two thousand years. The seat of empire was now transferred to Babylon, which became the only capital of the second Assyrian empire. With Nebuchadnezzar, who succeeded his father, Nabopolassar, shortly after the

overthrow of Nineveh, commences the grand era of Babylonian greatness. Babylon flourished, and became the mistress of the East, when Nineveh, her ancient rival, had become a mass of ruins. Most of the great works for which this capital was famous, are due to Nebuchadnezzar, or to his queen, Nitocris. The celebrated hanging gardens, familiar to every reader of history, and other stupendous creations of despotic power, possessing an unlimited command of wealth and labour, were added to Babylon in this reign. The Chaldæo-Babylonian empire, comprehending all Western Asia, as far as the Mediterranean, was now in the zenith of its glory On the death of Nebuchadnezzar it began to decline, and under his third or fourth successor, it fell into the hands of Cyrus the Mede, in the following manner:—"He came at last to Babylon," says Xenophon, "bringing with him a mighty multitude of horse, a mighty multitude of arms and javelin-men, but slingers innumerable." He made preparations as if to blockade the city, but the people laughed at the apparent folly of the undertaking, for Babylon contained within its walls, not only gardens and large open spaces for purposes of pleasure, but a sufficient quantity of land for tillage to support the inhabitants in the event of a siege, and they knew, therefore, that they had command of provisions for twenty years at least. But Cyrus had no intention of prolonging the siege. It will be recollected that the river flowed through the middle of the city, and the crafty Mede had formed a design of obtaining access to it by means of that channel. "He dug round the wall on every side," says Xenophon, "a very great ditch, and they threw up the earth towards themselves. In the first place, he built the turrets on the river, laying their foundations on palm-trees, that were not less than a hundred feet in length; and palm-trees that are pressed bend up under their weight, as asses do that are used to the pack-saddle. He placed the turrets on these for this reason, that it might carry the stronger appearance of his preparing to block up the city." The people laughed louder than ever at these immense preparations, and indulged in a feeling of reckless security, inspired by a fatal confidence. The ditches were finished, and on a night when the Babylonians had a great festival, Cyrus opened the sluices of the river into these vast reservoirs; the Euphrates deserted its ancient channel, which now became passable for an army, and Cyrus marched into the city and took possession. Thus Babylon was taken, and thus ended the second Assyrian empire, B.C. 538.



RUINS OF BABYLON.

The city was not at that time destroyed, although it was shorn of its glory, and its imperial honours. It now remained for two centuries subject to the Persian power, when, with the destruction of that monarchy, it fell under the resistless arms of Alexander the Great. It was here that the mighty conqueror died. One of his captains, Seleucus, received Babylon as his province; and, for a time, the Seleucidæ made Babylon the seat of an empire, which never rose, however, to play a conspicuous part in the world's affairs, but soon succumbed to the power of Rome, whose colossal form was now beginning to overshadow the world. Babylon was thus merged in the Roman empire, of which it continued for a period to form a distant and insignificant fragment. Gradually it dwindled away, and ultimately, though less suddenly, shared the fate of its ancient rival Nineveh, and sunk into desolation and ruin.

"Babylon is fallen—is fallen." This immense city has long been reduced to a few unsightly mounds, and has actually been buried in the soil for upwards of two thousand years. A succession of writers, down to the twelfth century of the Christian era, and the recent researches and excavations of travellers, enable us, however, to fix with certainty its site, and even to conjecture, with some probability, the relative position of its more remarkable buildings. Benjamin of Tudela, in the twelfth century, and other travellers down to the time of Niebuhr, have given a description of the mounds of earth, and fragments of massive walls, half buried in soil and sand, which constitute the only remains of the once magnificent Babylon; but we are indebted for the best account of its ruins to the late Mr. Rich, resident, on the part of the East India Company, at the court of the Pasha of Bagdad. The traces of the city begin to be perceptible near Mohaeril, a khan, or inn, nine English miles from Hillah, and thirty-eight to the south of Bagdad. The whole of the space between Mohaeril and Hillah exhibits here and there masses of brick and bitumen, and three mounds particularly attract attention by their magnitude. The largest of these is the Mujallibeh, which Rennel and Pietro de la Valle have conjectured to be the tower of Belus; it has a square superficies of 120,000 feet, and a height of only 28 feet. On digging into the earth accumulated on the summit, there were found layers of burnt bricks cemented with mortar, and occasionally whole bricks, with inscriptions on them. Beyond this is the mound Amram Ibn Ali, having an area of 104,000 feet, and an elevation of 23 feet; but the most important of the group is the Birs Nimroud, which Mr. Rich coincides with Neibhur in considering as the real tower of Belus. The square superficies of this mound is 49,000 feet; and the height of the east side is 60 feet, but on the west it rises to 200 feet in a conical form. It lies on the west side of the Euphrates, and if not originally distinct from Babylon, appears to have been the first separated from it. It is called by the Arabs, Birs Nimroud, the tower of Nimrod, and by the Jews the prison of Nebuchadnezzar. The kasr, or palace, is a mound of about 2,100 feet in length and breadth; and from the sculptures, inscribed bricks, and glazed and coloured tiles found there, it is generally regarded as the site of the large palace celebrated for its hanging gardens. The Amram Ibn Ali is presumed to have been the western palace. No very beautiful works of art have been found in these ruins; but bricks and gems, with inscriptions and sculptures, demonstrate the early connection which subsisted between the Babylonian and Persian empires. The inscriptions are generally placed on the lower side of the bricks, and were evidently not designed to be observed or read, being buried in a substratum of mortar. It has been inferred that they were magical formulas, or charms, to protect the buildings against evil spirits.

Tradition assigned the eastern bank of the Tigris, opposite to Mousul, as the site of Nineveh, and there travellers discovered un-

equivocal traces of a city of immense extent, which the recent researches of M. Botta, and more especially of our own illustrious

PALACE OF NIMROD—*Botta.*

countryman, Layard, have identified beyond doubt as the ruins of the mighty city of Nimrod. The discovery and excavation of the fragments of this magnificent city is one of the great achievements of our own day. For more than two thousand years its known existence in the world was a mere tradition; associated with which were ideas, believed to be more imaginary than real, of ancient and oriental magnificence—palaces, temples, and towers, all buried in the dust, and supposed to have left no traces except the exaggerations of history.

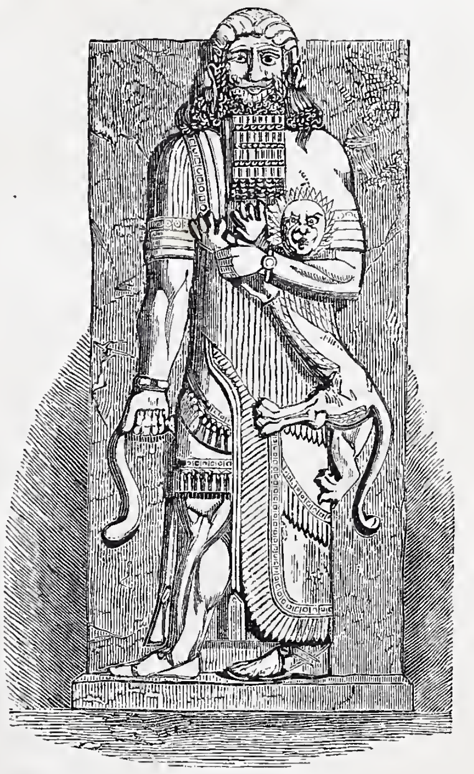
Suddenly this gorgeous vision of ancient power and grandeur, which loomed through the page of history, or blended with the vague reminiscences of dim and doubtful tradition, has been, in these latter days, realized. Nineveh has been exhumed from its long sepulture. It still remains, although in ruins, and even from a mass of shapeless mounds, which scarcely served to indicate its ancient site, the history of its former splendour has been drawn forth, its hieroglyphic inscriptions have been deciphered, its palaces have been ransacked for mysterious records, and the truth of history and tradition, in all material points, has been fully confirmed.

From ancient writers it appears that Nimroud, or the palace of Nimrod, in which the most striking discoveries have been made, was the first edifice with a royal park and a cluster of hamlets around it. In the course of years, other magnificent structures, the work of successive sovereigns, rose by its side, and, at length, when the older palaces were laid in ruins, other royal structures were reared on the spots now named Khorsabad and Karamles.

In a previous part of this work, while treating on the "Laws of Historical Evidence," we briefly referred to the discoveries recently made at Nineveh, and stated, at the same time, that a subsequent chapter would be expressly devoted to that subject. This will be appropriately introduced on a future occasion; and, therefore, we shall not at present interrupt the course of our history, by dwelling at length on the interesting figures and inscriptions which have been excavated from the ruins. We may remark, however, that religious symbols appear to predominate among the sculptures discovered, and that, from the vast preponderance of these developed in the ancient palaces of Nineveh, they seem to have been carefully invested with all the solemnity of temples. These temple-palaces were built on mounds, formed of an aggregation of bricks, the remains of three of which piles are still perceptible at Nineveh. Of the lofty structures themselves, enough of the ruins remain, buried among sand and dust, and covered over with vegetation, to give us a general idea of their construction. The walls were built of bricks, and varied from five to fifteen feet in thickness. Internally they were panelled with slabs of coarse alabaster, or gypsum, on the back of each of which was engraved an inscription recording the titles and genealogy of the king under whom the work was constructed. The entrances to the chambers were guarded by symbolical monsters—bulls and lions with eagles' pinions and human heads, from ten to sixteen feet in height—while under the threshold were deposited small images of the gods. The roof was composed of beams, supported by the walls; across these were laid twigs and branches, which were then plastered with clay. The rooms are all very narrow—a circumstance attributed to the fact that, in Assyria, there were no large trees fit for extended roofing. Accordingly, we find that the most famous hall of Nimroud, while nearly one hundred and sixty feet long, was only thirty-five in breadth. Simple as this structure may seem, the chambers were generally decorated with great splendour; the ceilings were beautifully painted, and often inlaid with ivory; the roofs were lofty, and sometimes supported by gilded columns; the walls were covered with emblematic ornaments, and striking historical sculptures, which formed, indeed, the records of the empire, each chamber being the pictorial history of a different scene.

There is one apparent defect in the construction of these palaces, which shows that, with all their splendour and costliness, they were deficient in one advantage possessed by the humblest structures of modern times. There is no appearance of any openings in the walls for windows, and, hence, it is inferred that the light was admitted through the roof—a conjecture, as Mr. Layard remarks, confirmed by the fact that a small drain leads from every chamber, as if for the purpose of carrying off rain-water. This gives us no superlative idea of the comfort of these abodes of royalty in ancient times.

There is evidence, however, that the arch, though claimed as a contrivance of comparatively modern date, was known to the ancient Assyrians. Among the remarkable discoveries made by Layard at Nimroud, was a vaulted chamber, built in the centre of a wall, nearly fifty feet in thickness, and about fifteen feet beneath the surface of the mound. The dimensions of this vault were ten feet in height



NIMROD.

by ten feet in width, and the arch over it was formed of kiln-burned bricks; but there was no apparent entrance, and no conjecture could be formed as to what purpose it had been applied. It shows, however, that the ancient Assyrians were acquainted with the principle of the arch—a fact which has been proved of the an-

cient Egyptians also, and of the Romans, in the later days of the empire; although it appears that they refrained from using it in their larger structures, perhaps from a knowledge of its self-destroying tendency, when on a large scale.

The drains already referred to, for removing the rain-water which fell into the chambers through the openings or windows in the roof, were constructed of tubular tiles; and there was under the pavement of the mound a main drain, the invert of which was formed of kiln-burnt bricks, and the upper part covered with slabs and tiles. It was likewise observed by Layard, that a thin layer of bitumen passed under all the floors and slabs, to preserve them, doubtless, from the damp, which would otherwise have risen from the earth beneath.

Without entering into details at present, we may state, in general terms, the important fact, which the recent excavations have fully established, that the arts had arrived at high perfection in ancient Nineveh. "The sculptures," says a writer on this subject, "are full and life-like, freer and more natural than those of Egypt, and many of the articles of furniture afford models worthy of imitation at the present day. The vases, formed of clay, are moulded with exquisite taste, and the metallic ornaments are of similar skill and beauty. Elaborate embroidery distinguishes the robes of the kings, and the ear-rings, bracelets, and clasps, worn by the court and the upper classes, are all of elegant form. The arms of the warrior, such as the hilt of his dagger and sword, were beautifully ornamented. Chairs and couches were formed of wood, the feet being constructed of metal, and were often inlaid with ivory." Ships of a rude construction are found on the bass-reliefs at Nimroud, and on those of Khorsabad and Kouyunjik are pictured naval engagements, showing that the ancient Assyrians were not altogether unacquainted with that method of warfare. At an early period the religion of Assyria had fallen into a corrupt species of Sabaism. Nature was deified in her various forms; and we find the sun, moon, stars, and zodiacal signs frequently engraven on the mystical cylinders which form so curious a remnant of her superstitions. Among the sacred sculptures, the composite animal forms are the most striking. Sometimes the deity is a hawk-headed figure, and sometimes he is represented as an eagle and lion united—symbols of wisdom, courage, and serene elevation.

The full historical value of the sculptures excavated from the ruins of Nineveh cannot yet be appreciated. A vast number of slabs are covered with characters, the key to which has only lately been discovered, and therefore only a few of them have yet been deciphered. Among these the curious wedge-shaped or cuneiform character abounds, of which there are three classes or forms, representing the literary usages of the Senectic, Persian, and Median nations. Amidst the ruins of all the ancient cities on the banks of the Tigris and Euphrates, bricks, cylinders, slabs, historical and symbolical figures of gypsum and alabaster, are seen everywhere marked with these rude and primitive inscriptions; and it has been conjectured that the tongue represented by this alphabet, found among the debris of these ruined cities and palaces, will, in all probability, be yet ascertained to represent that universal speech which prevailed when the earth was "of one language."

The first European travellers who were known to have formed any conjectures respecting the cuneatic characters were Pietro Delle Valle and Figueroa. Niebuhr published the earliest exact copies of cuneatic inscriptions; but down to the beginning of the present century no substantial progress had been made in interpreting them. The man who led the way into this treasury of antiquity was Professor Grotofeud, then a student at the University of Bonn, since director of the Gymnasium of Hanover. Without the advantages of Oriental learning, Grotofeud set himself to extract the latent meaning of one of the inscriptions copied by Niebuhr from a monument at Persepolis. He had no Greek manuscript to guide him, as in the case of the Rosetta stone, which, as we shall see in next chapter, afforded, for the first time, a key to the hieroglyphics of Egypt. The inscription upon which he commenced his labours was evidently written indeed in three languages; but whether either was a known tongue concealed under this curious alphabet was uncertain. He applied his entire energies to the subject. His first discovery was communicated in the year 1800 to the Royal Society of Gottingen, and after more than thirty years spent in patient investigation, he succeeded in determining nearly one-third of the alphabet. This result be arrived at by a lentative process. Assuming, in the first instance, that the inscriptions related to the kings whose portraits they accompanied, he proceeded to carefully examine and analyse them, word by word, and letter by letter, till at length he satisfied himself that he had found a genealogical succession of three distinct proper names—Hystaspes, Darius, and Xerxes. Grotofeud's great discovery was thus, in its beginnings, a mere guess; and yet he obtained in this manner the fragment of an alphabet, and approached the true mode of spelling so nearly, that those best qualified to form an opinion have never hesitated to adopt it.

Thus was laid an important basis for future labours; but nothing further was accomplished until, in 1836, M. Bournouf, a scholar distinguished for his intimate knowledge of the Zend, interpreted two of the inscriptions found at Hamadan, the site of the ancient Ecbactana, the capital of Media Magna. He likewise ascertained that one of the Persepolitan inscriptions contained numerous proper names of ten syllables, of which he was able to fix the true reading. The alphabet was thus considerably extended, and confidence in its power was so fully established, that it only needed the application of a critical knowledge of Zend, Sauscrit, and other dialects cognate to the ancient language of Persia, to solve the remaining difficulty. These requisites were found in Professor Lassen, of Bonn, the pupil of A. W. Schlegel, a man of almost universal Orientalism, who, between 1836 and 1844, published three memoirs, developing an alphabet which left scarcely anything further to be accomplished.

But the name of, perhaps, the most successful discoverer in this department of antiquarian research yet remains to be mentioned. "While the continental scholars," says Bonomi, in his recent work on *Nineveh and its Palaces*, "were working in their quiet studies on copies of inscriptions more or less accurate, by some happy fortune, a young officer of the East India Company's army, not behind any German recluse in antiquarian zeal, was attached to our mission in Persia. Colonel Rawlinson, being ignorant of what was going on in Europe, or of the processes by which Grotofeud had been led to the discoveries of which he had heard, set to work to decipher two of the inscriptions at Hamadan. He found them in every respect identical, except an epithet, and the groups being arranged, like Grotofeud's, genealogically, he applied the same process, arrived at the same conclusion, and succeeded in reading part of the text of the inscription. At this time Bournouf's work and the great Behistun inscription supplied him with abundant analogical and analytical aid; and he eventually succeeded in constructing an alphabet which only varied in a single character from that formed by Lassen at Bonn. One of the cuneiform alphabets had now been deciphered, and the language found to be an ancient Persian, easily interpreted by the analogies of modern Zend, and the Sanscrit of the Vedas. The industry and acumen of Colonel Rawlinson has worked out the problem so far, that farther inquiry will relate only to the refinements of grammatical criticism."

The same work had now to be performed for the Assyrian texts; and this, although attended with infinitely greater labour, has been to a certain extent accomplished. The Persian alphabet contained forty distinct characters; the Assyrian text appeared to contain six hundred. It was found, however, that some of these were only variants, or slightly deviating forms of the same letter; the most frequently recurring words were soon recognised, and when the sound had been approximatively determined, it was ascertained that the language was very nearly allied to the Hebrew and the ancient Chaldee. In spite of all the impediments which presented themselves, Colonel Rawlinson considers the meaning of about five hundred words to be certainly determined; and as these contain many substantives, verbs, and adjectives, with probably all the prepositions, they suffice to explain the meaning of any simple record of events, and such is the character of most of these inscriptions.

But on this subject Mr. Bonomi justly observes—"The great feats of interpretation which such a man as Rawlinson has accomplished, should not be suffered to blind us to the fact, that our materials for Assyrian history even now, after a partial elucidation of such inscriptions as have been found, are extremely limited and fragmentary, and in their present state convey little that is positive in its results, at least so far as a chronological narrative is concerned. The system of Assyrian writing is still extremely obscure, and the language which it records is only partially intelligible through the imperfect key of the Behistun inscriptions. Again, it should not be forgotten, though valuable as are the annals we possess of individual kings, and important as they may one day become as elements of a complete series, they go but a very little way towards filling up the gap of sixteen hundred years, which must have intervened between the age of Nimroud and the destruction of Nineveh by Cyaxares. All that we can expect at

present is, that the inscriptions may supply us with internal evidence respecting the relative position of the different royal families, and the probable interval which elapsed between them. Future discoveries of sculptures, and a farther development of the alphabet, are to be expected from the zeal of those inquirers now in the field, and to these we must look for the more complete elucidation of the history of Assyria."

On the interesting subject of ancient inscriptions we shall have more to say when we come to treat of the marvellous monuments of Egypt, with their mystic records. In the meantime we resume our summary of the Persian history.

A chain of mountains runs across Asia from the south-western angle of Asia Minor to the Caspian Sea,—the chain of Mount Taurus. From the eastern extremity of this chain several minor chains or spurs stretch downward to the shores of the Persian Gulf. The western slope of these mountains towards the Tigris were inhabited by the subjects of Babylon and Nineveh. The eastern side to the north was the land of the Medes; the southern extremity of the range was the land of the Persians. According to Herodotus there were six tribes or clans of the Medes, and nine of Persians. Five generations before Cyrus—whose name must be familiar to all readers of biblical history—the Median tribes had been brought into subjection to one head by Deioces. The descendants of that ruler had been engaged in frequent wars with their neighbours, the Assyrians of Nineveh. The Persian clans continued to be united among themselves by a lesser bond of union till the time of Cyrus. This crafty chieftain instigated his kindred clans—over whom the united Medes seem to have attained some advantages, in consequence of their looser organization—to attack their neighbours; and having made his kinsmen masters of the Medes, persuaded them in turn to allow him to be their master. The old hostilities between the Medes and tribes of Mesopotamia involved the new master of the former in a war with the latter. Nineveh, indeed, seems to have been taken by the last Median monarch a short time before the overthrow of his throne by Cyrus. Babylon was taken by Cyrus himself; and, by the conquest of these two mighty cities, the Assyro-Babylonian tribes were subjected to the Medo-Persian. Conquest infallibly leads to conquest, and war to war. Crœsus of Lydia, the seat of whose empire was in Sardis, had, about the time that Cyrus finally humbled the Assyrian power, subjected to himself all the Asian tribes north of the Taurus, and south of the river Halys. The two conquerors came in collision, and the fortune of Crœsus succumbed. Cyrus, not long after, fell leading his troops against the Scythians on the north-eastern frontier of his empire. His son, Cambyses, turned his arms in a south-western direction, overran the parts of Syria and Palestine not previously subjected by the Assyro-Babylonian monarchs, and the greater part of Egypt. These conquests were confirmed by his successors on the Medo-Persian throne; and, therefore, we have the limits of the Medo-Persian monarchy at the time it was brought into collision with the Greeks by its encroachments upon their colonies, extending along the coast from the innermost recesses of the Black Sea to the shores of Syria.

Over this wide expanse the whole power was in the hands of the united Median and Persian clans. The relation of the other inhabitants to these two races was that of subjection; their relation to each other seems to have been more that of incorporation. According to the Greek authors, the father of Cyrus was married to a Median princess. After the death of Cambyses, the short usurpation of a Magian priest was followed by the election of Darius, a Median nobleman, to the throne, in whose descendants the kingly character remained till the subversion of the monarchy. The subject Chaldeans—and, still more, their subjects—seem never to have been admitted to an equality in civil matters with the mountain warriors. The intra-Halytic tribes, too,—the tribes of Palestine,—seem to have been held in the same relative position of dependence.

Of the organization of the supreme power after the final establishment of the monarchy under Darius Hystaspes, we have a pretty clear notion from the descriptions of Greeks who visited, and were employed at, the Persian court, or at the courts of dependent satraps. It was excellent as a piece of skilful organization, but excellent only for the purposes of the monarch and of those who governed in his name. The state was divided into satrapies. In each a satrap wielded the civil and military power. His business was to preserve peace within his province, to uplift and transmit to the capital the royal revenue, and to bring into the field, at a moment's warning, the whole military force of the province, or as much of it as might be called for by the king. Throughout the empire, the distance between the most important cities was most accurately measured; resting stations were erected at convenient distances; and establishments for expediting royal messengers, and the conveyance of goods and travellers connected with the court, kept in constant efficiency. All this has an imposing appearance;—there is a neatness, a regularity, an efficiency, a clockwork-exactness, which pleases the taste. But, when we ask the use of this, the admiration is considerably allayed. The only check upon the monarch's will was the necessity of keeping in good humour his powerful nobles,—the chiefs of the Median and Persian clans. Within their satrapies, the power of the nobles who obtained these rich appointments would have been supreme, but for the necessity of disgorging for the use of the king a portion of the tribute they exacted from the people, and of following him in his wars. If a satrap withheld the tribute—if he disobeyed the royal mandate to call out and march his troops—if he was sufficiently tyrannical to goad the people to rebellion, and at the same time not sufficiently energetic to crush that rebellion, he might be looked upon at court as a bad governor, and displaced. In no other way could he incur the royal displeasure, except, indeed, from the whispered misrepresentations of courtiers. There was no security for the people in such a government. The Medo-Persian monarchy was in these days what the Ottoman empire is in ours,—a military occupation of the country—inhabited by a thousand tribes, differing in laws, customs, language, and religion—by one conquering tribe. The Persian monarch was a general, and encamped his forces in such a manner as to secure for themselves all the wealth of the country they occupied, with the power of making all male inhabitants capable of bearing arms, serve as auxiliaries in their wars. The well-calculated and specious organization of the public establishments had all these ends in view, and these only.

Of the domestic manners, of the languages, laws, and religions of the tribes held in subjection by this skilful organization, our knowledge is excessively scanty and confused. The Greeks, from whom our information is mainly derived, saw nothing but the dreaded Persian monarchy in this whole expanse of territory. Everything in their eyes was Persian, and had always been. Herodotus, under the influence of this confusion, after professing that his object is to trace the rise and progress of the hostilities between the Persians and Greeks, begins by enumerating the feuds between the Peloponnesian Greeks and the Trojans, and between the island Greeks and the Phenicians,—the Trojans and Phenicians being distant and distinct races, and neither of them, for long after, subjected to the Persian monarchy. The same confusion reigns, even in descriptions by the Greeks of what they witnessed with their own eyes. In describing the civil organization and religious hierarchy of special towns and districts, they never distinguish what was native and indigenous from what had been introduced by the ruling powers, or by the amalgamation of different tribes. The inextricable confusion hence arising may easily be conceived. The Persian monarchy was built up of the fragments of the Babylonian, Assyrian, Egyptian, and Lydian states. The Lydian had been built up of the fragments of many earlier and smaller states in Asia Minor. The Assyrian had been built up of the ruins of the Babylonian, Syrian, Hebrew, and Phenician states. Territories had been wasted and peopled by conquered hordes removed from a distance. The conquered had been forced to bow the knee to the gods of their conquerors. The conquerors, at the instigation of superstition or policy, had knelt in turn to the gods of the conquered. All was in itself confusion, and the hasty and superficial observation of the Greeks made confusion worse confounded.

In the Belus of the Chaldean we may trace the Baal of Scripture,—the early object of adoration of the Aramaic tribes. In the Hercules—so called by the Greeks—of Tyre and Carthage, we possibly have the same divinity. In the Venus Urania of Cyprus and the nearest shores of Syria, we have the Ashtaroth, Queen of Heaven, of the Sidonians. Mithra, we are informed, was the Persian object of adoration; whether the sun, or an incorporated divinity of the imagination, it is hard to say. The name Magi is common to a body of priests about the time that the Greeks and Persians came most closely into collision, and to a Median tribe. The name Chaldean is in like manner common to the priests of Bel at Babylon, and a warlike nation.

## NATURAL PHILOSOPHY AND CHEMISTRY.

### CHAPTER XVIII.

ON THE PRESENT STATE OF VOLTAIC ELECTRICITY AND ELECTRO-MAGNETISM.

PART I.—VOLTAIC ELECTRICITY.—(*Continued.*)

65. IT appears to be the opinion of Faraday that in diluted nitric and sulphuric acids, the affinity of the oxygen of the water alone acts on the positive element; in such case, when water acts in opposition to these acids, they must either develop no current, or, if the affinity of the oxygen be increased by their presence, display a more powerful electro-motive force than pure water; notwithstanding experiment proves that in the greater number of cases investigated, these acids act more weakly than water.

66. It was remarked by Becquerel in the year 1828, that when zinc and copper are placed in two cells separated by membrane, and filled with a solution of sulphate of zinc, the addition of a little nitric acid to the solution in the copper cell strengthens the current, but to that in the zinc cell, weakens it. This experiment, although sometimes assumed to favour the chemical theory, has a very different effect when duly considered and rightly apprehended. Fechner has also met with similar results in the course of his elaborate investigations.

67. The observation made with regard to the two acids are also applicable to caustic potash and ammonia; in fact, all the caustic alkalis always differ in their action from water, and also from acids, and that instantaneously, at the very first moment of immersion, before the zinc has lost possession of its full metallic lustre, so that the action can scarcely proceed from formation of chloric or oxy-combinations; there is, however, apparently a certain relation between the degree of action and the positive condition of the positive element, which may be evidenced by comparison of the iron circuits with those of zinc and tin; but it is not intelligible, according to Faraday's views, why both alkalis with the iron circuits, and the ammonia with tin circuits, have generally a weaker action than water, while with the combinations zinc-platina and zinc-silver, the alkalis have the ascendancy. The same principle holds good in all those cases in which two oxy-combinations are opposed to one another; for instance, water and carbonate of soda, sulphate of zinc and borax, sulphate of magnesia and borax, sulphuric acid and borax.

68. The opinion of Faraday that substances produce a more powerful current the more difficultly decomposable they are, and *vice versâ*, although it might appear to derive some support from the fact of solutions of carbonate of soda and borax, which are easily decomposable salts, always succumbing to that of the second oxy-combination, cannot be reconciled with his notion of the sole emanation of the current from the combination of the positive metal with the oxygen, chlorine, or other negative element of the electrolyte; for if the evolution of the current depended upon such combinations alone, the stronger the force which bound the positive and negative elements of the electrolyte together, the less activity would there be in the exertion of the affinity between the negative element and the positive metal, and therefore the less electro-motive force, whereas the contrary should be the case; therefore both positions cannot hold good. This is further proved by the fact, that the alkalis, in almost all cases, increase the electro-motive force, and at the same time render water more decomposable than it is of itself. We may adduce as an additional example, salt and sal-ammoniac, two chlorides, the solution of the latter of which develops a more powerful electro-motive force than that of the former; but it will not be asserted that sal-ammoniac is more difficult of decomposition than salt.

69. Since it is established that solution of chlorine, sulphuric acid, nitric acid, ammonia, oxygenated water, peroxide of hydrogen, the quinto-sulphuret of potassium, and other non-electrolytes, exercise a decided influence on the development of the electro-motive force, it becomes necessary to alter Faraday's position, that the activity of the voltaic pile is due alone to the employment of fluids which are electrolytes; to this extent—that while we recognise the principle that the fluids between the metallic elements must be decomposable, for the reason that conduction rarely occurs without decomposition—we cannot admit that the force developed by the contiguity of the fluids and metals necessarily depends upon facility of conduction or of decomposition alone, inasmuch as this force can be increased or diminished by fluids which are not capable of direct decomposition, and therefore are not electrolytes.

70. Dilute hydrochloric acid when combined with silver or with copper—no matter whether the positive element be zinc, (common or amalgamated,) iron, or tin—possesses in a high degree the superiority over the solution of iodide of potassium, which fact when compared with the opposite one, on substitution of platinum for silver or copper, clearly shows that the two metals in the circuit take an essential part in the production of the electro-motive force, and therefore leads us to conclude that the terms "generating," and "conducting," when limited in reference to the voltaic current, the first to the positive metal, and the second to the negative, are extremely incorrect; it is proper therefore to caution the reader, should he meet with those terms in the progress of this treatise, not to consider the negative metal as employed for the single purpose of conduction.

71. It is singular how the opinion of the negative metal being useful alone for conduction, can have obtained such general recognition, while so many well-established facts have so long existed against it. It is evident that if the negative element in the circuit had merely to act passively, or rather to exercise only the function of conducting, the best conductor ought to afford the strongest current, in other words, the greatest electro-motive force; for this reason, copper, which is a far superior conductor to platina, should produce a far greater force than the latter, but this is not the case, for platinum combined with a positive metal, forms a much more powerful circle. Indeed, the importance of the negative element in the generation of the current would appear to follow from the principle established by Fechner, "that in cases where fluids do not act very alteringly on the metals, *the voltaic law of the tensions is also valid for the electro-motive forces of the circuit*," and that, therefore, for instance, the electro-motive force of a zinc-platina circuit is equal to the sum of the forces of a zinc-copper and of a copper-platina circuit.

72. The researches of Pouillet have thrown much light upon our knowledge of the conducting powers of various bodies for voltaic electricity, and the results he has arrived at enable him to express the relative conducting powers of the different metals by the following numbers:—

| | | | |
|---|---|---|---|
| Palladium, | 5791 | Brass from | 900 |
| Silver, | 5152 | „ to | 200 |
| Gold, | 3975 | Cast steel, from | 800 |
| Copper, | 3838 | „ to | 500 |
| Platinum, | 855 | Iron, | 600 |
| Bismuth, | 384 | Mercury, | 100 |

73. The relative conducting powers of the saline solutions, usually employed in voltaic combinations, have also been determined by Pouillet; and he has found that the conducting power of platinum is two million and a half times that of a saturated solution of sulphate of copper, while that of copper is sixteen million times as great: taking the conducting power of a saturated solution of sulphate of copper at 10·000, he ascertained the conducting power of

| | |
|---|---|
| A saturated solution of sulphate of zinc to be, | 4·170 |
| Distilled water, | 0·025 |
| Distilled water with $\frac{1}{20000}$ of nitric acid, | 0·150 |

74. These amazing differences in the conducting powers of various fluids will render intelligible how retardation occurs, in a greater or less degree, when the current has to pass an interposed liquid of considerable length. Pure water may

almost be considered an absolute non-conductor, when weak circles are employed; and, although the experiment has been frequently made with most powerful combinations—some of them constructed for the special purpose—it has been ascertained that the current cannot pass before completion of the circuit through the smallest appreciable interval of air. The belief entertained by many, that a spark, evidencing the passage of a current, was seen on making contact, and therefore that the current passed before the metals touched, strengthened the belief that chemical action should be alone considered the source of its development; but since the experiments referred to have been promulgated, this, one of the strongest arguments in favour of the chemical theory, has been abandoned, and it is now generally admitted that no spark passes until the electrodes have touched and are again parted; and that even then, the transit is accomplished by a divellent action of the current, aided by heat and inductive polarization, upon the particles at the end of the positive electrode, which being thus forcibly separated from one electrode, are attracted by and convey the current to the other.

75. M. Marianini has also investigated the relative conducting powers of aqueous solutions of various salts, alkalis and acids; and as the results of his experiments appear to be important, we have compiled from his extended list a table of the ratios of conductibility of those solutions which are more or less employed in voltaic combinations,—water being taken as unity. The substances are placed in the order of their conducting power:—

| Substances dissolved in 100 parts water. | Conducting power. | Substances dissolved in 100 parts water. | Conducting power. |
|---|---|---|---|
| Chloride of platinum, | 418·00 | Phosphoric acid, . . | 127·00 |
| Nitric acid, . . . . | 358·00 | Chloride of calcium, | 110·00 |
| Chloride of gold, . . | 307 00 | Tartaric acid, . . | 98·66 |
| Nitrate of silver, . . | 298·00 | Acetic acid, . . . | 87·00 |
| Nitrate of copper, . | 278·00 | Chloride of sodium, | 84·79 |
| Sulphate of copper, . | 258·00 | Sulphate of potash, | 80·00 |
| Sulphuric acid, . . | 239·00 | Nitrate of potash, . | 78·03 |
| Muriatic acid, . . . | 164·00 | Chlorate of potash, . | 68·09 |
| Acetate of copper, . | 154·00 | Sulphate of zinc, . | 51·64 |
| Muriate of ammonia, | 150·00 | Liquid ammonia, | 26·45 |

76. With respect to the saline solutions, it is to be observed that the power increases according to the quantity of salt dissolved, but that the increase progresses more slowly as the point of saturation is approached; it is also worthy of remark, what a high position muriate of ammonia holds in the scale; it appears that it takes precedence of many acids, of most of the metallic, and of all the alkaline salts,—advantages which, coupled with its peculiar action, when in connexion with the positive element, render its employment most beneficial in voltaic combinations, and bestow upon it a marked superiority over acid solutions, including those which apparently possess higher conducting powers.

77. The resistance of metals to conduction of electricity has been accurately ascertained by means of the degrees of heat evolved by the passage of a current of equal intensity through different metals: the heat developed in conducting wires is in proportion to the extent of surface of the positive plate—no matter whether the current emanate from a single cell, or a series of cells. The following table shows the degrees of heat evolved by an equal current from different metals, measured by the pressure of expanded air upon a column of alcohol:—

| Metals. | Heat evolved. | Resistance. |
|---|---|---|
| Silver, . . . . . . . . | 6 | 1 |
| Copper, . . . . . . . . | 6 | 1 |
| Gold, . . . . . . . . | 9 | $1\frac{1}{2}$ |
| Zinc, . . . . . . . . | 18 | 3 |
| Platinum, . . . . . . . | 30 | 5 |
| Iron, . . . . . . . . . | 30 | 5 |
| Tin, . . . . . . . . . | 36 | 6 |
| Lead, . . . . . . . . | 72 | 12 |
| Brass, . . . . . . . . | 18 | 3 |

78. It is apparent that the conducting powers of the above metals are inversely as these numbers—silver being a better conductor than lead, in the ratio of 12 to 1. Heat appears to diminish the conductibility of all, so long as they preserve their elementary condition; but when in combination, in the condition of oxides, chlorides, iodides, chlorates, nitrates, sulphates, &c., whatever increase of heat renders them fluid, also causes them to become conductors: this law appears, however, only to hold good with metallo-basic combinations—the only exception to those hitherto examined being periodide of tin.

79. The investigations of Pouillet and Ohm have established the law first promulgated by Davy, namely, "that the conducting power of a metallic wire is inversely as its length, and directly as its section." To this law may be added the conclusions deduced by Faraday from his valuable experiments:—

1st, All bodies conduct electricity in the same way, from metals to lac and gases, but in very different degrees.

2d, Conducting power is in some bodies powerfully increased by heat, and in others diminished, yet without our perceiving any accompanying essential electrical difference, either in the bodies, or in the changes occasioned by the electricity conducted.

3d, A numerous class of bodies insulating electricity of low intensity when solid, conduct it very freely when fluid, and are then decomposed by it.

4th, But there are many fluid bodies which do not sensibly conduct electricity of this low intensity; there are some which conduct it without being decomposed, nor is fluidity essential to decomposition.

5th, There is but one body yet discovered, the periodide of mercury, which, insulating a voltaic current when solid, and conducting it when fluid, is *not* decomposed in the latter case.

6th, There is no strict electrical distinction of conduction which can yet be drawn between bodies supposed to be elementary, and those known to be compound.

80. It appears that those compound bodies whose elements proceed to the same electrode, after decomposition, are non-conductors, which affords a reason why oils, camphor, resins, and caoutchouc, are, even when melted, non-conductors. This law would appear also sufficient to show why liquid phosphorus, chlorine and sulphur, are non-conductors; but the conducting power of metals when liquid as well as solid, is left unexplained by it.

81. Perfectly conducting bodies are not sensibly affected by electricity passing through them; but if the sectional area of the conducting substance be diminished as the quantity of the current is increased, the evolution of heat becomes perceptible, and the conductor, if metallic, becomes red hot, and if the quantity is still more augmented, it melts and is vaporized.

82. The results of the most accurate experiments that have been made upon the subject appear to indicate, that the ratio of the current in its passage through metals to the heat evolved, is as 2 : 3; in other words, if the quantity be doubled, or the sectional area of the metallic conductor reduced to one half, the increase of heat evolved is tripled.

## PROPERTIES OF THE METALS.

The metals constitute by far the most numerous class of undecompounded bodies in chemical arrangements. They are, in general, readily distinguished from other substances, by characters which every one recognises; but to an ordinary observer, they do not appear to differ essentially from one another; they seem rather to owe their differences of colour, and other physical properties, to a tinge and character given to them by adventitious circumstances, and perhaps some trifling admixture of other substances. This opinion is natural, and was at one time the prevailing doctrine of the

learned. When chemistry began to be developed in the hands of the alchemists—upon whom it has been fashionable to heap ridicule for the extravagances of their notions—it was generally admitted that all metals were essentially the same, and as gold was reckoned the most precious, it was assumed to be the pure basis of all the other metals. Upon this assumption, the aim of alchemy was direct and rational; its object was to separate the substance, whatever it might be, the presence of which prevented lead and other *base* metals from being gold. It is hardly necessary to observe, that these efforts failed; accordingly, modern chemists, taught by experience to believe the required decomposition impossible, have come to the matter-of-fact conclusion, that when metals are of different colours, degrees of hardness, lustre, ductility, fusibility, and so on, that they are of different natures.

Although the metallic character be readily and popularly recognised, it is difficult to define it with accuracy. With the single exception of quicksilver, the metals are all solid at ordinary atmospheric temperatures; but their most striking property is their lustre, which is so remarkable as to be at once understood by the expression, *metallic lustre.* This property belongs in a greater or less degree to every metal; it is the property of strongly reflecting light, and seems connected with a certain state of aggregation of the metallic particles. The same property is however possessed, at least superficially, in a minor degree, by mica, animal charcoal, selenium, and polished indigo—bodies not at all metallic.

In consequence of the peculiar power of the metals to reflect light, they are no less remarkable for their opacity than their lustre. Thus, silver-leaf, only one hundred thousandth of an inch in thickness, is perfectly opaque, and leaves of other metals in general, allow no light to pass through their substance; yet gold-leaf of the two hundred thousandth part of an inch in thickness, would seem, as observed by Newton, to transmit green rays of light; and it is probable, that could we obtain films of other metals of equal thinness, they would be found to allow certain rays to pass through them. The fact, as observed with gold, has however been ascribed to the porosity of the metal; the rays transmitted passing through an infinite number of minute fissures in the thin leaf. This, it must be admitted, is quite compatible with perfect opacity of the substance of the metal; the leaf, like a piece of wire gauze allowing the light to pass only through its interstices, and not through the solid metal itself, which may be perfectly impervious to all luminous rays.

As formerly explained, the polished metals are imperfect radiators and receivers of heat, but they are excellent reflectors both of light and heat: hence their peculiar fitness for the construction of mirrors. They are also in general excellent conductors of heat, and most of them also of electricity, though probably not all. The greater number of them are susceptible of assuming the crystalline form. With several of them this may be effected by fusion and slow cooling. Thus, by suffering the melted metal in a crucible slowly to concrete externally, and then perforating the solid crust, and pouring out the liquid interior, the cavity so formed will be found lined with crystals. This experiment succeeds extremely well with bismuth, which furnishes a singular congeries of cubic crystals. When a metal is precipitated by another, it is often deposited in a crystalline state. Thus, if a little mercury be thrown into a solution of nitrate of silver (lunar caustic,) the silver is precipitated in beautiful crystals. The same phenomenon occurs, when a bit of zinc is suspended in a salt of lead. In like manner, if a stick of phosphorus be immersed in a silver solution, it becomes incrusted with beautiful metallic crystals, which after some time perfectly incase the phosphorus. Gold is also sometimes deposited in crystals from its ether solutions; and, during the decomposition of several of the metallic solutions, by galvanic electricity especially when low powers are employed, beautiful metallic crystals are often obtained. This is readily verified with solutions of copper and silver salts.

The metals possess in different degrees a peculiar tenacity, which in its greatest perfection renders them *malleable* and *ductile*—that is, capable of being extended under the hammer, and drawn into wire—properties which belong to no other species of matter. Thus gold and silver may be beaten into leaves almost inconceivably thin; copper, tin, platinum and lead possess the same property, but less perfectly: others are entirely destitute of it, as arsenic, antimony, and cobalt. These last can indeed be readily reduced to fine powder, and hence they are distinguished as brittle metals. Those metals which are malleable, are also ductile; these properties are analogous, but do not appear to bear a uniform relation to each other among the metals possessing them. Gold and silver are, however, the most ductile, as they are the most malleable. Thus, a grain of gold may be extended by hammering, so as to cover fifty-two square inches of surface, or it may be drawn into 500 feet of wire; and by enveloping it in silver, it may be extended to 700 feet. In like manner, platinum, which is inferior to copper and tin in malleability, has been drawn into wire not more than the $\frac{1}{300000}$th of an inch diameter—a degree of fineness, which, except under certain circumstances of illumination, is invisible. Iron may be drawn into wire as fine as the human hair; copper is less ductile; and zinc, tin and lead, can be drawn into wire, but considerably less fine. The brittle metals, as might be supposed, do not draw.

The following table shows the order which the metals bear to one another in respect to these properties:—

| Order of Malleability. | Order of Ductility. | Order of Tenacity. | Order of Brittleness. |
|---|---|---|---|
| Gold. | Gold. | Iron,......1000 | Antimony. |
| Silver. | Silver. | Copper,... 550 | Arsenic. |
| Copper. | Platinum. | Platinum, 494 | Bismuth. |
| Tin. | Iron. | Silver,.... 349 | Cerium. |
| Cadmium. | Copper. | Gold,...... 273 | Chromium. |
| Platinum. | Zinc. | Zinc,...... 199 | Cobalt. |
| Lead. | Tin. | Tin, ...... 63 | Columbium. |
| Zinc. | Lead. | Lead,...... 50 | Manganese. |
| Iron. | Nickel. | —— | Molybdenum. |
| Nickel. | Palladium. | Iron wire of | Tellurium. |
| Palladium. | Cadmium. | $\frac{1}{10}$th in. diame- | Titanium. |
| Potassium. | | ter is capable of | Tungsten. |
| Sodium. | | sustaining 500 | Uranium. |
| Solid mercury. | | lbs. avoirdupois. | Rhodium. |

Few of the metals, when pure, are very hard, and some are so soft as to yield to the nail. The following table of hardness is given from the experiments of M. Dumas:—

| | | | |
|---|---|---|---|
| Titanium, Tungsten, Manganese, | are harder than steel. | Chromium, Rhodium, | scratch glass. |
| Platinum, Palladium, Copper, Gold, Silver, Tellurium, Bismuth, Cadmium, Tin, | are scratched by calc-spar. | Nickel, Cobalt, Iron, Antimony, Zinc, | are scratched by glass. |
| | | Lead—yields to the nail. | |
| | | Potassium, Sodium, | are soft as wax at 60°. |
| | | Mercury, | is liquid above 39°. |

In respect to *fusibility*—that is, the capability of being melted by heat—the metals differ from each other as widely as in any other respect. Thus mercury requires to be cooled down to 39° before it becomes solid, whereas the melting point of platinum is somewhere beyond 3280°. Potassium melts at 140°, and sodium at 190°. Tin becomes liquid at 444°, bismuth at 500°, lead at 600°, zinc at 770°, and antimony at 800°. Silver, gold, and copper, require a bright cherry red heat to melt them (about 2000°); cast iron, nickel, and cobalt, a white heat (about 2800°); and manganese and malleable iron, the highest heat of a smith's forge, (about 3000°). The highest temperatures of our furnaces are only sufficient to agglutinate very imperfectly the metals

molybdenum, uranium, tungsten, and chromium; and titanium, cerium, osmium, iridium, rhodium, platinum and columbium, require the intense heat of the oxy-hydrogen blowpipe, or that of voltaic electricity, to fuse them. Some of the metals when exposed to heat, not only melt; but, obeying the general law of liquids, boil and evaporate when the heat is sufficiently high. Thus mercury, zinc, cadmium, bismuth, tellurium, and antimony, boil and evaporate at a red heat; and in a vacuum, mercury is known to evaporate at ordinary atmospheric temperatures (above 50°); silver and lead require a high heat to vaporize them; tin a still higher heat, and gold will only evaporate slowly under the most intense heat that can be applied. Several of the other metals, as iron and nickel, cannot be made to evaporate in the most intense heat with which we are acquainted. Arsenic on the other hand evaporates without melting.

There are several of the metals which emit a peculiar odour, especially when rubbed, or have their temperature slightly raised. This is particularly the case with copper, iron, and tin. The vapour of others is very remarkable. The arsenic vapour has the smell of garlic; that of tellurium smells like horseradish; and osmium takes its name from the smell of its vapour (*osme*, odour.) Some of the metals have also a peculiar taste when applied to the tongue, which has been ascribed to their electrical condition; but it must be remarked that many of the most oxidable metals are entirely destitute both of taste and odour.

A high *specific gravity* was reckoned one of the most marked characteristics of the metals, till the recent discovery of the metallic bases of the alkalis by Sir H. Davy. So intimately indeed was the metallic lustre associated in the mind with great weight, that when a piece of potassium was put for the first time into the hand of an eminent teacher of chemistry, in admiring its perfect metallic character, he poised it upon the finger, and exclaimed, *How heavy!* and the prejudice was only removed by seeing it float upon water. The list of the metals, however, includes the densest forms of matter with which we are acquainted, and although great weight cannot be regarded as a universal property, we have few examples in which the density is less than the density of water. These examples comprehend only potassium and sodium; all the other metals are of greater specific gravity up to platinum, which is twenty-one times the weight of an equal bulk of water.

The degrees of facility with which the metals combine with oxygen differ widely. Some, by mere exposure to the atmosphere, absorb its oxygen with great rapidity: such is the case with potassium and sodium; others absorb it more slowly, as manganese, iron, and arsenic; and lead and copper still more slowly. Others again do not oxidate by exposure to air, unless at a high temperature; this is the case with tin, zinc, mercury, antimony, bismuth, and cobalt, which absorb the oxygen readily when in a state of fusion. Others again do not oxidate by exposure to air and heat, or by immersion in water, as gold and platinum; the same is nearly true of nickel and silver. The tendency of the metals to combine with oxygen appears however to be greatly influenced by their mechanical condition; for some of them which are only slowly oxidized by exposure to air and heat, are rapidly acted upon when in very fine mechanical division even at common temperatures.

In combining with oxygen under heat, some of the metals burn with great splendour; this is exemplified in copper, zinc, tin, and bismuth; iron filings, when thrown even into the flame of a candle, and very fine iron wire, when held in the external part of the flame, take fire and throw off beautiful scintillations. Antimony burns at a white heat, and tellurium burns before the flame of the blowpipe. In short, at intense heats most of the metals may be burned, and if placed in the flame of the oxy-hydrogen blowpipe, they deflagrate with intense brilliancy and great facility. On the other hand, potassium burns by contact with a piece of ice, with as much intensity as others do in the oxy-hydrogen flame.

The metals, by combination with oxygen, lose their metallic characters, and form an important series of definite compounds, known as the *metallic oxides*. These have very different characters and properties; even the same metal not unfrequently affords oxides which differ from each other widely in properties and appearance. Thus, 50 parts of mercury, combining with 1 part of oxygen, produce a black oxide; and with 2 parts of oxygen, the oxide is red and highly poisonous. Many of the metals thus afford more than one oxide; and it is to be observed. that when the same metal unites in more than one proportion with oxygen, the oxygen in the second and higher oxides bears a definite arithmetical relation to the first; and when two oxides are thus formed, that having the minimum of oxygen is termed the *protoxide*, and that with the maximum of oxygen, the *peroxide*. This law of definite proportions will be fully explained hereafter.

Among the combinations of metals with oxygen, some are soluble in water and alkaline, such as the *fixed alkalis*, soda, potash, and lithia, and the *alkaline earths;* others are soluble and sour, forming the *metallic acids*. Some are insoluble in water, and have neither taste nor smell; and many, when taken into the stomach, act as poisons. Thus, oxide of arsenic is a notorious and virulent poison; oxide of copper is less virulent than arsenic; oxide of lead is a painful poison; oxide of nickel is also destructive of life; and the peroxide of mercury, unless in small quantities, is likewise poisonous.

The metals, for the most part, may be combined with each other, forming a most important class of compounds, known as the *metallic alloys*. Many of these are more useful than the metals of which they are composed, and possess properties a good deal different from their elements. One of the best known and most serviceable of all the alloys is brass—a compound of zinc and copper; it is harder, more easily melted, more close in the texture, better coloured and less liable to tarnish than copper; it is less brittle, and in every way more valuable than zinc. Pinchbeck is composed of the same ingredients as brass, but in different proportions, the zinc predominating. Copper and tin are two very soft and flexible metals, which being fused together form the alloy, known as bell-metal, which is harder than iron, very brittle, and very sonorous. The same materials in different proportions form speculum metal, and the kind of ordnance, improperly called brass cannon. Pewter is composed of tin and lead—sometimes with the addition of zinc, copper, or bismuth. Plates, upon which music is stamped, are composed of tin and antimony, and printing types are formed of an alloy of lead and antimony, with a slight addition of bismuth. Tin-foil is an alloy of tin and lead, and plumbers' solder is composed of the same metals. Fusible metal is a compound of bismuth, lead and tin, with sometimes a little mercury. An *amalgam* of zinc and mercury is used for exciting electric machines, and that of mercury and tin is the compound employed for *silvering* looking-glasses. Gold coin is an alloy of gold and copper, in the proportion of 11 to 1; and jewellers' gold is an alloy of the same metals, in the proportion of 3 gold to 1 copper. *Green gold* has silver instead of copper. Silver coin, in like manner, is an alloy of silver and copper, in the proportion of 37 to 3. These alloys of gold and silver are harder, and consequently less liable to wear than the pure metals.

It is worthy of remark, that in the formation of alloys, the metals in the act of combination generally evolve heat. For instance, when platinum and tin-foil are fused together, there is the most vivid ignition, and when zinc and copper are suddenly mixed, in the proportion to form brass, the increase of heat is such as to vaporize part of the metal.

The alloys are formed by various processes, depending upon the nature of the metals employed. Most of them are prepared by simply fusing the two metals together; but if there be a considerable difference in their specific gravities, the heavier very generally subsides, and the lower part of the mass thus differs in composition from the upper. This may be in a great measure prevented by agitating the alloy

till it solidifies, but this is not always convenient. Thus, in stereotype plates, which are cast vertically, the upper side usually contains more antimony than the other. The same is observed when an alloy of gold and copper is cast into bars: the mould being placed perpendicularly, the upper part of the bar contains more copper than the lower. Copper and silver evince the same tendency to separate: although they appear readily to combine, it is found extremely difficult to form a bar of their alloy of perfectly uniform composition throughout. Many of the alloys, however, appear to be true chemical compounds; and in some cases the metals unite in definite proportions only. It is, indeed, not improbable, that wherever metals do form alloys, that the alloys so formed are definite compounds, and that any undue quantity of either metal present, simply mixes mechanically with the mass. Thus, among the artificial as well as natural alloys, there are many which crystallize; and in some cases, the true compound may be separated from the mere mixture of the superfluous metal by the process of crystallization.

The tendency of the metals to unite with other elements, and with each other, prevents their being often found disseminated in mineral nature in their pure metallic state. Some of them do occur so nearly pure as to be called *native metals.* Thus, gold is found only slightly alloyed with silver and copper, and platinum occurs as an alloy of iron, palladium, iridium, rhodium, and osmium. Silver, copper, mercury, antimony, bismuth, arsenic, and tellurium, occur both in the native metallic state, although never absolutely pure, and also mineralized with other bodies. Lead, tin, zinc, iron, antimony, and several others, are extensively disseminated as sulphurets, that is, combined or mineralized by sulphur. The native metallic oxides are also plentiful, and the chlorides are not uncommon: iodides and bromides are rare, and we have no carburets or phosphurets. Native carbonates are, however, abundant, and phosphates and also sulphates are not rare.

The combination of a metal with its mineralizing substance, is what we denominate an *ore;* and it is in this state of ore that metals occur, when they are not found native. The ores are exceedingly diversified in appearance; sometimes they possess metallic lustre; sometimes they appear stony, at other times earthy. In some instances they are crystallized into regular forms, but more commonly they occur in shapeless masses. The ores are chiefly found in *veins*—that is, large fissures in rocks, especially the granitic, schistous, and limestone rocks; but sometimes they are found in rounded and detached fragments disseminated through certain alluvial and diluvial strata of the earth. The extraction of the metal from them is denominated their *reduction,* and implies a laborious series of operations, mechanical and chemical, comprehended under the term *metallurgy.*

The following table contains an enumeration of the metals, and may be useful for reference. The column headed "equivalents," shows the weights which unite with 8 oxygen, to form the oxides, and the succeeding column contains the symbols by which the metals are denoted in systematic chemistry.

| Names of Metals. | Authors, and Dates of their Discovery. | | Specific Gravity. | Melting Points. *Fahr.* | Equivalents Hydrogen = I. | Abbreviations or Symbols. |
|---|---|---|---|---|---|---|
| 1. Gold (Aurum) | Known to the ancients. | | 19.25 | 2016° | 200 | Au. |
| 2. Silver (Argentum) | | | 10.47 | 1873 | 108 | Ag. |
| 3. Iron (Ferrum) | | | 7·78 | 2800 ? s.f.* | 28 | Fe. |
| 4. Copper (Cuprum) | | | 8·89 | 1996 | 64 | Cu. |
| 5. Mercury (Hydrargyrum) | | | 13·56 | 39 | 200 | Hg. |
| 6. Lead (Plumbum) | | | 11·35 | 612 | 104 | Pb. |
| 7. Tin (Stannum) | | | 7·29 | 442 | 58 | Sn. |
| 8. Antimony (Stibium) | Basil Valentine | 1490 | 6·70 | . . | 65 | Sb. |
| 9. Bismuth | Agricola. | 1530 | 9·80 | 497 | 72 | Bi. |
| 10. Zinc | Paracelsus ? | 1530 | 7·00 | 773 | 32 | Z. |
| 11. Arsenic | Brandt | 1733 | 5·88 | . . | 38 | Ar. |
| 12. Cobalt | | | 8·53 | 2810 ? | 30 | Co. |
| 13. Platinum | Wood | 1741 | 20·98 | oh. bp. † | 99 | Pl. |
| 14. Nickel | Cronstedt | 1751 | 8·27 | 2810 ? | 30 | Ni. |
| 15. Manganese | Gahn | 1774 | 6·85 | s. f. | 28 | Mn. |
| 16. Tungsten (Wolfram) | D'Elhuiart | 1781 | 17·60 | . . | 100 | W. |
| 17. Tellurium | Müller | 1782 | 6·11 | 620 ? | 32 | Te. |
| 18. Molybdenum | Hielm | 1782 | 7·40 | oh. bp. | 48 | Mo. |
| 19. Uranium | Klatroph | 1789 | 9·00 | oh. bp. | 217 | U. |
| 20. Titanium | Gregor | 1791 | 5.30 | oh. bp. | 24 | Ti. |
| 21. Chromium | Vauquelin | 1797 | . . | oh. bp. | 28 | Cr. |
| 22. Columbium (Tantalum) | Hatchett | 1802 | . . | oh. bp. | 185 | T. |
| 23. Palladium | Wollaston | 1803 | 11·50 | . . | 54 | Pd. |
| 24. Rhodium | | | . . | oh. bp. | 52 | R. |
| 25. Iridium | Tennant | 1803 | . . | oh. bp. | 99 | Ir. |
| 26. Osmium | | | . . | oh. bp. | 100 | Os. |
| 27. Cerium | Hisinger | 1804 | . . | . . | 48 | Ce. |
| 28. Potassium (Kalium) | Davy | 1807 | 0·86 | 136 | 40 | K. |
| 29. Sodium (Natronium) | | | 0·97 | 190 | 24 | Na. |
| 30. Barium | | | . . | . . | 70 | Ba. |
| 31. Strontium | | | . . | . . | 44 | Sr. |
| 32. Calcium | | | . . | . . | 20 | Ca. |
| 33. Cadmium | Stromeyer | 1818 | 8·60 | 442 | 56 | Cd. |
| 34. Lithium | Arfwedson | 1818 | . . | . . | 8 | L. |
| 35. Silicium | Berzelius | 1824 | . . | . . | 8 | S. |
| 36. Zirconium | | | . . | . . | 33 | Zr. |
| 37. Aluminum | Wöhler | 1828 | . . | . . | 14 | Al. |
| 38. Glucinum | | | . . | . . | 18 | Gl. |
| 39. Yttrium | | | . . | . . | 32 | Y. |
| 40. Thorium | Berzelius | 1829 | . . | . . | 60 | Th. |
| 41. Magnesium | Bussy | 1829 | . . | . . | 13 | Mg. |
| 42. Vanadium | Seftström | 1830 | . . | . . | 69 | V. |
| 43. Lantanum | Mosander | 1840 | . . | . . | ? | Ln. |

* Smith's forge. † Oxy.-hydrogen blowpipe.

# BOTANY.

## CHAPTER I.

### INTRODUCTORY OBSERVATIONS AND DEFINITIONS.

The works of creation are generally considered as forming three great divisions, popularly styled the three kingdoms of Nature,—the animal, the vegetable, and the mineral; and these, superficial observers are apt to think, are sufficiently widely separated from one another, by a sufficiently broad line of demarcation. If we look closely into them, however, we shall find that there are but two great divisions in the eye of the philosopher—the organic and the inorganic. The most prominent distinction which subsists between the various natural objects which surround us, is derived from their possessing, or being destitute of, an *organized* structure; their having, or not having, *organs*, fitted for carrying on certain *actions*. The want of organization is the characteristic of mere inert matter, and affords an evidence of the absence of a living principle; and it is a clear proof that there has been no life in these bodies, either during their formation, or their increase. On the other hand, the slightest trace of organization discovered in any natural object, is a complete proof that life *is*, or at least *was once*, present in that object.

The separate particles of which unorganized bodies are composed, are either *elementary atoms*, or *compound molecules*, in which certain elementary atoms are united together by the force of chemical affinity, in a definite proportion. Thus, a bit of the shining calcareous spar of which chimney-piece ornaments are made, consist of many molecules, or minute grains, united together into a mass. Each of these molecules again, how small soever it be, consists of an atom of lime united to an atom of carbonic acid; and in the hands of the chemist, these two constituents can be disunited and exhibited separately, by the aid of simple enough processes and appliances. When these molecules are permitted to become solid, after having been melted by heat, or dissolved in some powerful acid, they arrange themselves into various regular mathematical forms called crystals. These crystals can increase in size only by the addition of new matter *to their outside*; they do not *grow*, or increase *from within*. When peculiar circumstances do not permit the component particles to arrange themselves into crystals, they still combine into shapeless masses, possessing the same chemical composition as if they had been crystallized. All such natural combinations of unorganized matter are called simple minerals; and compound minerals are just heterogeneous mixtures of fragments of simple minerals, (as granite consists of mingled pieces of quartz, mica, and felspar), and of those simple and compound minerals, the earth which we inhabit is entirely composed.

Organized bodies are made up of the same elementary constituents as those which compose unorganized bodies, but not in the same proportions, nor exactly in the same combinations. They are, however, completely and satisfactorily distinguished from the latter, by the presence of a living principle within them, and by the manner in which they increase. Their chemical constituents are not united; so that their composition is homogeneous throughout, like that of simple minerals; nor do they form various composite grains which are irregularly jumbled together, as in compound minerals, but are arranged so as to form a number of *organs*, or parts which are fitted to carry on certain actions, or perform certain functions which are necessary for the life of the individual. The increase of organized bodies is not produced by the addition merely of new particles to their outsides, but by a process of *growth*. This growth takes place by the deposition of new particles in among the old; and this addition of new particles to others like them already in the body, is called *assimilation*, (Latin, *making like*). This process of assimilation is carried on by the nourishing particles passing into certain cavities in the inside of the living body, or tubes running through them, called *vessels*, from which they are again deposited where they are wanted, and become alive. Thus, the food taken into the stomach of an animal becomes converted into blood; the blood is carried through the blood vessels into all parts of the body, and is deposited where it is wanted; where bone is wanted, it becomes bone; where flesh is wanted, it becomes flesh; where skin is needed it becomes skin.

This process of assimilation depends on that mysterious principle which we call *life*, something quite different from any of the forces to which inorganic bodies are subjected, and capable of controlling, and to a certain extent of counteracting the effect of these forces. The most striking peculiarity in the vital force, or power of life, is its varying intensity at different times, so that at one time the actions of the living body are maintained in full vigour, and at another, carried on with languor; and its decrease at a certain period of existence, so that the creature in which it resided shall cease to grow, shall decay, and finally cease to live, the constituents of its body becoming decomposed, to unite again in new forms, and contribute to the growth again of new creatures.

The organized division of Nature, it has already been remarked, comprises two kingdoms—the animal and the vegetable, and our daily observation is sufficient to satisfy us of the propriety of such a division. Yet it is extremely difficult, and has hitherto baffled the attempts of naturalists to define precisely their boundaries. No definitions of what is a plant, and what is an animal, have yet been found sufficiently precise to separate all the conditions under which different organized bodies are found; for even to this day, there are some objects of which we are yet in doubt under which kingdom they should be arranged. The most constant, if not quite a universal distinction, and one which all can understand, between animals and vegetables, is, that the former only are provided with internal cavities, or *stomachs*, into which their food is taken to be digested, before it be fitted for final assimilation.

Among the higher classes of both kingdoms indeed, there is no difficulty in pointing out the line of demarcation; but as we descend in the scale of each, we find an increasing similarity in external characters. The addition of *sensibility* to the living principle may be considered a more characteristic property of an animal, an endowment by which an individual is rendered conscious of its existence and its wants, and by which it is induced to seek to satisfy these wants by some actions depending on its will. It has been supposed, and some experiments would almost seem to confirm the supposition, that a sense of pain is very nearly if not entirely absent, in many of the lowest tribes of animals. If this be true, the lines of the poet will have lost their point, who says,—

> "The little beetle that we tread upon,
> In corp'ral sufferance, feels a pang as great
> As when a giant dies."

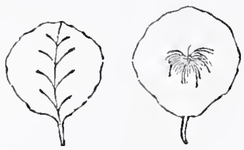
But then we have no means of ascertaining whether the case be so or not, and we should avoid putting the poor creatures to the test of what may be a most cruel experiment.

Botany, in the more extended sense of the term, may be considered as embracing every inquiry which can be made into the various phenomena connected with the Vegetable Kingdom. These inquiries may have respect to three different sets of objects; 1st, The investigation of the outward forms and conditions in which plants are met with; 2d, The examination of the various functions which they perform while in life; and 3d, The laws by which their distribution over the earth's surface is regulated. For practical purposes, the results of these inquiries may be conveniently arranged under two heads. The one may be called the descriptive department of the science, or Descriptive Botany. It includes the examination, description, and classification of all the circumstances connected with the external figure and internal structure of plants. While attending to this division of the subject, we consider vegetables much in the same way as we would study the component parts of

some complicated machine, of whose several portions we must have some knowledge separately, before we can expect to understand how they work together in connexion, or to appreciate the purposes which each was intended to subserve. In Physiological Botany, which is the other department, we are to consider these machines as if in action, —to investigate the phenomena produced upon the machinery by the moving power, which is the living principle; in fact, we are to trace the plants which we select for our study, from their origin by seed, through their growth, to their fructification, and to their final withering and decay.

Notwithstanding that this separation of anatomy from physiology looks well in laying down a system, it is found best in practice to conjoin them, so as after describing parts, to proceed to explain their uses. In the ensuing articles, then, care will be taken to explain the structure of the various parts of plants in a natural order, so that the uses of one set of parts having been fully unfolded, will naturally lead to the description of the set which are next called into play in the growth and life of the vegetable.

In all descriptive sciences, as anatomy, chemistry, mineralogy, and botany, there is a series of *descriptive terms*, ordinary words which have not the same latitude of signification which they admit in ordinary language, and peculiar words expressing peculiar forms or qualities, which we are not led perhaps, to remark particularly, in the cursory view which we take of the objects to which they refer, in the ordinary circumstances in which we come in contact with them. Each of these terms has a strictly limited signification, so that when we meet it, we know *exactly* what it denotes. Thus the words *round* and *orbicular*, in common language mean the same. But in botany a round leaf is circular, with the stalk at the edge, while an orbicular one has its stalk inserted at or near its centre. When, therefore, we meet the word orbicular in the description of any plant, we know exactly the form of leaf indicated, so that we cannot mistake it for any other.



It is absolutely necessary, then, for the practical student, to have a *glossary;* that is, a list of all the terms used, substantives and adjectives, to which he can refer as a dictionary, and which, by and by, he will have completely transferred to the tablets of his memory. In the papers to be given in this Journal, it would be out of place to attempt a dictionary of this kind; and such a task is the less necessary, because to those who are so much pleased with the sketch given of botany, as to study it practically, a book is necessary, called a *Flora*, and to most of these a glossary of terms is prefixed.

Everybody knows that Flora was the name given by the Romans to their goddess of flowers; and her name is now used for a book containing a systematic botanical description of the plants of a particular country. Thus we have a Flora Britannica, containing descriptions of all the plants which are natives of Great Britain; a Flora Laponica, describing all the plants in Lapland; a Flora Americana, telling us about the plants in America; and on a smaller scale, a Flora Glottiana, enumerating all those which are natives of Clydesdale.

The book called a Flora, then, is arranged like a dictionary, and you search it till you find a description corresponding to the specimen you have in your hand, and thus you ascertain its name, its connexions, its localities, its habits, and its uses. And although the various kinds of plants are so many, that above 2400 species of flowering plants are enumerated as natives of Britain, there is no difficulty in finding out most of them, after having got grounded in the terms used, and somewhat practised in the mode of applying them. The best native Flora is "A Systematic Arrangement of British Plants, by Dr Withering, corrected and condensed, with an Introduction to the Study of Botany, with Figures and Glossary, by W. Macgillivray," who has now been rewarded for his long and successful devotion to Natural History, with the Professorship of that subject in the Marischal College at Aberdeen. The best proof of the value of this book is, its having run through five editions, and its price is so moderate as to put it within the reach of any student.

But after having examined a plant, and ascertained its name and qualities, it is often desirable to preserve it, so that it can be referred to at a future time. A good specimen is selected, and laid in a natural position between sheets of soft grey paper, placed between two boards, and subjected to pressure. The paper is changed daily, until the plant has become quite dry and stiff. It is then fixed on a sheet of paper, on which its name is written, the place where it was gathered, with the date, and any other memorandum that may be thought of. When these specimens accumulate, they are arranged in families, so that they can be afterwards easily referred to. A collection made in this way is called a *herbarium*, or *hortus siccus*, (dry garden.)

In 1738, the celebrated Linnæus, Professor of Physic at Upsal, in Sweden, published his famous work on botany—creating the science at once, if one may use such an expression. Previous to his time, botany was a mere list of plants, with some not very accurate descriptions of their external appearance. His powerful mind, of which the distinguishing characteristic was the capacity for generalization, saw that as all plants are alive, and have the power of producing successors, each must have a set of reproductive organs, the form and number of which will serve for a ground of classification. Various modifications of arrangements have since his time been made, but after all, the Linnæan system is the best of all for the purpose of a dictionary, and especially for those who are commencing the study.

Linnæus remarked, that in plants, as in animals, there is a distinction of sexes, into male and female—the females being those in which the seeds of the young progeny appear, and on which the care of producing and nourishing them is devolved, until they be capable of their independent existence. In a large proportion of plants, the males and females can be discriminated from one another; and, of these plants, he formed a great division, which he called Phænogamous, from two Greek words, signifying an open marriage. In the remaining division of plants, the germs which are to form the young appear in a different manner; there is no difference which would lead us to call one male, and another female, and hence he called this division Cryptogamous, from the Greek word, signifying a concealed marriage. The investigation of the cryptogamic plants is very difficult, so our glance at them shall be deferred, till we arrive at our concluding article.

A few words must now be said concerning classification.

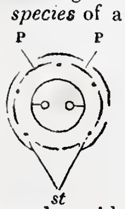
Objects which have some important character common to them all, are arranged together, to form a CLASS. Then, on examining these again, several differences are observable among their characters, less important, however, than those in virtue of which they stand in the same class. According to these, the class is divided into several ORDERS. In each order, again, there are differences, less important than those which distinguish the order, and by these it is divided into several Genera. Descending to still more minute differences, we find that each genus may generally be subdivided into several *Species*. The *Species* includes under it the individuals, of which, collectively, it is composed. In some species, we observe slight differences, not sufficient to form what we call a *specific* character, and yet sufficiently constant, and here we call the specimen a *variety*. It must be obvious to you, that the character of a CLASS will be very short, as expressing just some great and well-marked difference; that the character of an ORDER may be perhaps, but not necessarily, longer; that the definition of a Genus *must* be longer, as expressing *several* facts; and the description of a *Species* must, in general, be longer still.

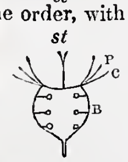
Let us now apply this to Linnæus' classification of plants. He divided the whole vegetable kingdom into classes.

orders, genera, and species: the classes and orders according to the number, proportion, figure, and situation of the stamens and pistils, *i. e.*, males and females; the genera formed of groups of species, with similarly constructed parts of fructification; and the characters of the species derived from the variations of form in the other parts, as the flower, leaves, stem, and root.

Thus, of those plants which possess 5 *stamens*, he formed a class, which he called *Pentandria*, (Greek, 5 men); these again he subdivided into orders, according to the number of *pistils*, those having but one, forming the order *Monogynia*, (Greek, *one* woman); these with two pistils, the order *Digynia*, (Greek, *two* women,) and so on. The next subdivision, that into *Genera*, is of great importance, for a *genus* is a natural group, independent of all artificial arrangement, and essential to every system. A very superficial observation will discover that a number of *species* are naturally arranged into the group constituting a *genus*, agreeing generally in their habits and form, and readily distinguishable from all other plants. Thus, the red and black currant, differing from each other in the shape and colour of the fruit, the form of the leaves, &c., yet both belong to the same *genus*, whose systematic name is *Ribes*. The same may be observed in the different *Roses*, *Geraniums*, and so on; but the *species* of many *genera* are not so evident, and require a more particular observation.

The character of a *genus* is formed from the number, figure, proportion, and situation, or connexion of the parts of fructification. But the science has been much simplified, by adopting what has been called the *essential generic character*, consisting of those parts only, of the fructification which are sufficient to distinguish the genus from all others in the class and order to which it belongs, without describing the other parts. Thus, should we find that all the *species* of a genus have 5 *petals*, it is a sufficient *generic* character to say "petals 5." But if other *genera* in the same order have 5 petals, then some other character must be added, taking care, for the sake of brevity, that no unnecessary one be employed. Thus the currant has 5 *petals*, but so have other five genera of the class *Pentandria*, order *Monogynia*, in Macgillivray's Flora. We find there a small subdivision of the order, with the *petals superior*, that is implanted above the *germen*, and hence we find the currant characterized as having a "berry, many-seeded, calyx bearing the petals, style cleft."




The *species* are distinguished by lesser differences, often not depending on the parts of fructification. Thus, if there are but two *species* of a *genus*, and the one has the *round* leaf, and the other the *orbicular* one, already figured—this is a sufficient distinction. When the *species* in any *genus* are numerous, other differences must be sought for to aid in distinguishing them.

Botanists are universally agreed in applying two appellations to each plant—the former being the name of the *genus*, the latter of the *species*;—thus, *Ribes rubra* is the red currant, being the species rubra of the genus *Ribes*. The names are all Latin, as is the practice in almost all the sciences, in order that they may be the same to scientific people all over the world. In a carefully printed Flora, the *generic* name is printed with a capital letter, and frequently in capitals altogether; while the *specific* name is in small letters, and begins with a small letter, except when it is a proper name, as the name of its discoverer, or of the place where it is most usually found.

A table of the classes and orders will be found in the next article.

# GEOLOGY.

## CHAPTER XIII.

### THE CARBONIFEROUS SYSTEM.

The rocks of the carboniferous system generally repose on old red sandstone, and attain a thickness of 2,000 yards or more. They are commonly divided into the mountain limestone, the millstone grit, and the coal measures. The lowest of these, the mountain limestone, consists of beds of marine limestone and shale, a few grits, and little or no coal; but in Scotland and the north of England, the group contains beds of workable coal, and presents the ordinary characters of a coal formation—namely, alternations of shale, sandstone, ironstone and coal, with beds of limestone abounding in marine remains. The central portion of the carboniferous system contains, in some places, coarse grits used for millstones—hence the name *millstone grit*. It consists besides these of marine limestones, shales and sandstones, and thin beds of coal and ironstone. The only difference in the truo coal formation, or upper portion of the system, is, that it does not contain marine limestones, and the beds of coal are thicker and more valuable than in the lower divisions.

The following is the statement given by professor Phillips, of the succession or thickness of strata in the north of England:—

*Coal formation*—a mass 1000 yards or more in thickness, consisting of indefinite alternations of shales and sandstones of different kinds, with about 50 feet of coal; in many beds somo ironstone layers, and, very rarely, thin layers of limestone.

*Mountain limestone*—a mass of calcareous rocks with very few partings of argillaceous matter, almost no grits, no coal, some chert nodules, and occasionally layers of red oxide of iron: 500 to 1500 feet in thickness.

The system in Derbyshire consists of:—

1*st*. *The coal formation.*

2*d*. *The millstone grit group*—a series of very pebbly quartzose and felspathic sandstones, and some thin beds of bad coal—several hundred feet.

3*d*. *Limestone shale*—a nearly uniform series of laminated shales or plates, mostly bituminous, with some ironstones and thin black limestones, but no coal: 1000 feet or more.

4*th*. *Mountain limestone formation.*

In Yorkshire there occur—

1*st*. *The coal formation.*

2*d*. *The millstone grit*—a series of three, mostly pebbly, grit stones separated by shales, flaggy freestones, thin limestones, ironstones, and several beds of coals: 1000 feet.

3*d*. *Yoredale rocks*—consisting of five or more limestones, with many freestones, flagstones, ironstones, chert and several coal seams: 1000 feet.

4*th*. *Scar limestone*—divided by partitions of grits and shales, and some beds of coal.

In the west of Scotland we have:—

1*st*. The upper coal formation, containing from twenty-four to thirty seams of coal, seven or eight of which are of workable thickness, though seldom so in the same section, the alternating strata consisting of white gray grits and laminated sandstones; clay and bituminous shales, carboniferous ironstones: about 2000 fathoms in thickness.

2*d*. Three or four blue limestones, with overlying thick beds of clay shale, containing marine remains, thick beds of grit and laminated sandstones, some bands of clay ironstone and thin seams of coal: about 100 fathoms.

3*d*. Under coal formation—a series of sandstones and shales, containing two or more black-band ironstones, and several seams of cubical and cannel coal: about 70 fathoms.

4*th*. Beds of shale, with numerous bands of clay ironstone, several limestones, one or two coal seams, and some sandstones: 150 fathoms.

5*th*. Beds of gritty sandstones and conglomerate, &c.

6*th*. Beds of thin friable shale, with 60 or more thin layers of compact limestones. No organic remains.

7*th*. Old red sandstone.

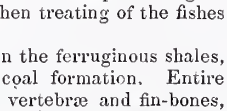
In a paper recently read at the London Geological Society, Mr Lyell describes the coal formation of Nova Scotia as of enormous thickness, and as containing through a great extent of that thickness, fossil trees perpendicular to the lines of

stratification; many of their stems are from 20 to 30 feet in length, and 2 feet or more in diameter. The fossil plants of the Nova Scotia coal field are strictly analogous, if not identical, with those of the British coal formations. These are the stigmaria ficoides, the calamite, the sigillaria, the lepidodendron, the flabellaria, the sternbergia asterophyllites, and many varieties of the filices or fern tribe. Plants belonging to these genera are found in every division of the carboniferous system in which coal occurs.

The shales abound with the impressions and casts of univalve and bivalve shells, amounting to nearly 400 species; above 100 of which are brachiopods, above 90 gasteropods, about 80 cephalopods, and 80 other varieties of bivalves not included among the brachiopods. About 60 per cent. of the species belong to extinct genera; and the brachiopods which, in the present ocean, are not above 1 to 100, were about 1 to 3 in the carboniferous era. 12 species or more of bivalves, having the external form of unios or river muscles, are met with in the upper coal formation. Conchologists are not agreed as to the fluviatile or marine origin of these shells. One argument in favour of their fresh-water origin is certainly of great weight, viz., they are never met with in beds in which shells decidedly marine, or in which corallines or crinoideæ, are found; all of which are absent from the upper coal formation. The beds in which they are met with, abound in the remains of ganoid fishes; such are the megalichthys, the palæoniscus, the holoptychius, and the dorsal spines of the gyracanthus, ctenocanthus, &c.—fishes which probably existed, rather in the large rivers and estuaries, than in the ocean of that ancient period. Some of these fishes must have been of extraordinary dimensions, if we may estimate their size from the remarkable fragments which sometimes are disclosed in the coal formation. Some of these indicate a fish nearly 60 feet in length. The fishes are chiefly of a sauroid character, their jaws being armed with sharp conical teeth. Their bodies were clad with rhomboidal, enamelled scales, and in general their conformation resembled the osteolepis, the figure of which is given in the last chapter, when treating of the fishes of the old red sandstone.

The remains of fishes occur chiefly in the ferruginous shales, connected with the ironstones of the coal formation. Entire fishes are not common; teeth, scales, vertebræ and fin-bones, are of most frequent occurrence. The remains of the megalichthys are met with in the limestone of Burdiehouse, near Edinburgh, which is one of the lowest members of the carboniferous series; they are also found in the newest shales of the upper coal formation of Lanarkshire—a circumstance which shows that that species was propagated through the entire era of carboniferous deposition.

Fossil crustaceans are of rare occurrence in the rocks of the carboniferous system; but trilobites do occur in the limestones of the lower series, and we have seen a very fine specimen of one of the lobster tribe, in limestone, in the neighbourhood of Paisley; and two other very singular crustaceans in the possession of Dr Scoular of Dublin, which were obtained from the same bed. The limestone in which these occur, appears to be a very low member of the lower series, and contains beautiful impressions of many rare fern plants, with shells of the genera chiton, terebratula, producta, &c. Fossil flies occur very rarely in these rocks. One of these was discovered impressed on coal shale, connected with one of the upper coals, near Glasgow, by Dr. Paterson, of Free St. Andrew's Church of that city; and we have the wing of a lepodipterous insect of a bright golden colour set in calcareous spar, which was found in the fissure of a sandstone of the coal formation about 24 feet from the surface, in the parish of Shotts. Other insects have been found in the same formation; so that during the carboniferous era, we have the most distinct evidence of the existence of not only land plants, but of an order of animals adapted to live on land or skim the surface of the deep—all evidence of their prior existence is wanting in rocks of an older date.



Corallines and crinoideans are very abundant in the carboniferous limestones, whole layers being sometimes entirely composed of them. The corals are frequently much comminuted, and entire crinoideans are exceedingly rare. The carboniferous system, then, furnishes evidence of the contemporaneous existence during the period of its deposition of a Fauna consisting of corallines, crinoideans, conchifera, mollusca, crustacea, fishes, and insects; and of a Flora, in which plants requiring a humid soil and atmosphere, and tropical heat, grew in vast luxuriance, and contributed to the formation of those supplies of coal which we find so abundantly stored up for the use of the human race in the formation we treat of.

That coal is of vegetable origin is not denied by any one who has paid the slightest attention to the subject; but to account for all the phenomena of a coal-field, and above all for such vast accumulations of vegetable matter as must have been required to furnish the coal itself, is perhaps the most difficult problem of geological science. The difficulty in question, however, by no means invalidates the fact of the vegetable origin of coal; that is based on evidence the most incontrovertible.

If we examine the under or upper layer of almost any coal bed, we will find it to be composed of laminæ, the surfaces of which are distinctly marked with vegetable impressions, the under and upper surfaces of each being alike. Fifteen or twenty laminæ or plates often occur in the thickness of an inch, in which several plants—such as the fluted sigillaria, the reticulated lepidodendron, the transversely striated calamite, the dotted stigmaria, or the sedge-like flabellaria—are distinctly observable. As the coal becomes largely cubical, or completely compact, the vegetable impressions disappear; but are again to be observed whenever the coal becomes impure from an admixture of clayey matter, which seems more than anything else to have prevented the complete metamorphosis of the whole mass. The plants which occur in this state are always much compressed; stems more than a foot in diameter being reduced to the thinness of a farthing, a circumstance which shows that they were either of a hollow or succulent nature. Plants of the same genera often occur in sandstone and sometimes in shale without being compressed, measuring from one to three or even four feet in diameter, and with large branching roots ramified in the rocks. It is very remarkable that the roots are rarely or never met with in the coal beds, as in the sandstones and grits; nor are they met with in the fire-clays, that almost universally underlie the coal beds, which they undoubtedly would be, had these, as has been supposed, formed the soil in which they grew. It is also no less strange that these fire-clays seldom or never contain any other plant except the stems and leaves of the stigmaria ficoides, which, as far as our observation has gone, exhibits no trace of a root. This plant occurs almost always in a horizontal or very slightly inclined position in the strata, and very often with leaves spread out latterly from the stem, and so regularly that it is impossible to indulge the belief that they grew elsewhere than on the spots where they are now found. The phenomena to which we allude are not peculiar to any particular strata or series of the carboniferous rocks; on the contrary, it is met with in the sandstones, in the shales, and in the ironstones, throughout the whole vertical range of the system. We have not, however, observed stigmaria with leaves attached in the laminated ground coal already referred to, but have met with them in argillaceous parrot or cannel coal. Nor are the leaves always horizontal; they often penetrate the sandstones in all directions. The almost universal entanglement of its leaves and stems in the muddy clay of the formation seems to prove that it was aquatic in its habits, and grew probably at the bottom of shallow water, into which, in rainy seasons, the mud may have been carried which formed the clay, and at the same time carried along a large quantity of the plants, then peculiar to the land, which may have continued to float on the surface of the water till they became water-logged, giving nourishment, in the mean time, to immense quantities of equiseta flabellaria, and other aquatic or marsh plants; while stems of the sigillaria and the lepidodendron broken from the soil, without the roots being extracted from it, were borne from time to time towards the accumulating vegetable mass and deposited. A process, somewhat analogous to the growth of peat moss, might afterwards be maintained; and, in process of time, the material necessary to constitute a coal-bed, might be amassed. The theory is not without its difficulties; but it seems to be beset with fewer than the supposition, that the whole of the vegetable matter was drifted from a distance. A coal-bed of six or eight feet thick must have required the superposition of several hundreds of succulent plants, such as the laminated coal, already alluded to, indicates the coal plants to have been. What body of water could have sustained

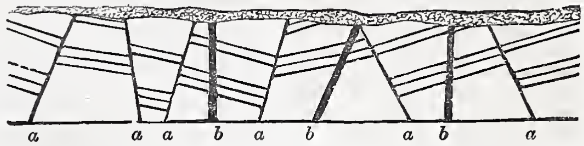
such an accumulation; and from whence could they have come? Had these plants, as is supposed, been drifted from a distance, it is scarcely possible to conceive that a mass equal to that instanced, requiring the superposition of several hundreds of plants, could have taken place without the waters which deposited them having, during the period of deposition, been charged from time to time with argillaceous or other matter, foreign to the nature of coal. This, in fact, we find to be frequently the case; but intervening masses of coal are frequently so thick as to belie the supposition, that they could be derived from any floating or drifted mass of vegetable matter.

The great areas over which a coal-bed frequently extends, and its almost uniform thickness, seem also adverse to the drift theory; for, under what supposable circumstances, except something analogous to the formation of peat, can we suppose it possible that areas of hundreds of square leagues should at one time have been covered with drifted vegetation? Almost all the sandstones and arenaceous shales, at whatever depth they may occur, are ridged with ripple mark. This we know to be occasioned by the efflux and reflux of the tide. Shallow water, therefore, seems to have been necessary to have impressed these marks upon the lower as well as the higher beds of the carboniferous rocks; if so, then, repeated subsidences must have taken place, and the coal may have been produced near the surface as we have supposed. But the evidence does not close here. In the strata, the upright stems of trees are not unfrequent, which evidently shows proximity to the surface at the time of growth; and as coal-beds are accumulated above such vertical stems, subsidence in the area of deposition is clearly shown to have taken place. But the agencies by which repeated subsidences occurred, cannot yet be said to have been satisfactorily explained; and there are certainly phenomena connected with the coal formation adverse to the supposition of coal being always derived from plants which grew on the spot. For instance, if the coal plants grew on the area now occupied by the coal-beds, we might naturally expect to find their roots in the fire-clays which immediately underlie them; but these, as far as our experience has gone, are never met with; the stigmaria ficoides forming the sole plant found therein. Again, the coaly laminæ, which intervene between the fire-clays and the true coal, though consisting solely of layers of plants converted into coal, exhibit no trace of roots, and very rarely of leaves. We may also mention a curious fact, that in the blackband ironstones near Airdrie, there are sometimes layers of perfect coal; stems of calamites, &c., converted into coal, also occur, with stems of the stigmaria ficoides, having the leaves attached, and spread out horizontally, and quite parallel with each other. The same stratum contains a vast number of compressed bivalve shells, while the top layer contains in many places immense quantities of fish scales, teeth, &c.; the latter are also occasionally met with in the lower layers of the band, and sometimes in the stratum itself. Here, then, we have the most decisive evidence of coal being formed in water in which fishes lived, and also of the growth of the stigmaria in the same medium. Another blackband ironstone, wrought at Keppoch, near Glasgow, consists frequently of alternate layers of coal and ironstone; yet in the same stratum the deep-sea shell Lingula occurs in millions together, with fish scales, teeth, and sometimes entire fishes. Such coal must have been formed in water, and could not have resulted from plants growing where their remains are now found.

The facts stated in the above remarks are alluded to rather to court inquiry into, than to solve the very important question, whether our beds of coal are derived from plants which grew on the area of deposition, or whether the vegetable mass came from a distance; or how far both agencies may have contributed to produce the phenomena we behold?

Theories are only safely indulged in when the relative facts are sufficiently known and accumulated; and this cannot yet be asserted as the case with regard to the history of the true origin and formation of coal. The facts, which may be regarded as established, are, its vegetable origin—repeated subsidence of the surface during the era of deposition — the growth of trees in places where coal now exists;—but as to the agencies by which the vast masses requisite to form our coal-beds were accumulated, no satisfactory theory has as yet been propounded.

Coal-fields are generally traversed by faults and dykes. A fault is a dislocation of the strata, by which the beds are displaced from their original continuity, and placed on either side of the fracture at a greater or less distance from the surface, as in the following diagram:—




*a a a* Faults.—*b b b* Dykes.

Dykes are walls of foreign matter, generally of igneous origin, cutting the strata in a perpendicular or inclined position.

Faults are frequently of great vertical extent—the strata having been tilted up, in some instances, to more than 150 yards—a coal-bed being at the surface on one side of the fault, and at that depth on the other. What, we may ask, has become of the superior beds before the fracture took place? The coal on either side must have been equally covered with the superincumbent strata, yet the surface is now quite level. What was the agency by which the upthrown mass was denuded, and the present level produced? Here, again, we are forced to contemplate the operation of causes to which we have either no equivalent in the present economy of nature, or forced to take into calculation the slow operation of existing causes through the lapse of ages, the duration of which baffles the conception of beings so shortlived as we are; but, when we take into consideration the immense degradation of previously indurated matter which must have taken place before the earth's entire strata could have been built up by the hand of time, the abrasion to which we allude seems as nothing, and the time necessary for effecting it as of trifling amount amidst the immensity of the past. Faults, however vexatious they sometimes prove in arresting the progress of the miner, are very useful in preventing the flow of water from the portion of the coal which lies on the other side—the clayey matter of the fracture acting as a dam, and confining the water to its particular portion of the field. Faults have evidently been produced by pressure from beneath, occasioned, probably, by the same subterranean force which ejected the trap dykes, or those overlying beds of igneous rocks which are of so common occurrence in coal-fields.

Dykes are generally composed of greenstone, or greenstone porphyry. In almost every instance they destroy the coal in contact; and, in some places, to a considerable distance, by depriving it of its bituminous matter, but in others the coal is converted into anthracite used in kilns; and a smithy coal is often the product, which generally sells much higher than common coal. Dykes sometimes lie obliquely to the plane of stratification, and masses of trap are sometimes injected horizontally. In every such case the coal in contact is burnt and wasted; and even coals at a considerable distance are destroyed or deteriorated in quality. Dykes vary in width from a few inches to many yards, and in any coal-field generally run nearly parallel to each other. Those in the Scottish coal formation run from east to west, or between that and south-east to north-west, which is also the bearing of the leading faults and mineral veins both in England and Scotland.

"The surface of country occupied by the carboniferous and medial system is proportionally much larger in the British islands than in other parts of the globe. In Ireland, the greatest part of the plains and broadly undulated interior consists of mountain limestone, in some places covered by coal measures, and in others supported by old red sandstone. In fact, excluding the parts previously described, as gneiss, mica schist, clay-slate, and greywacke-slate, and a large tract of later strata, (red sandstone, green sand, chalk, &c.,) capped by basalt, extending from Lough Neagh to Lough Foyle, and to the sea-coast of Antrim, nearly all the rest of Ireland belongs to the carboniferous system."

In Scotland, the carboniferous rocks are skirted by old red sandstone or trap-rocks, in a line passing from St Abb's Head in Berwickshire, south-west to the neighbourhood of Girvan on the Ayrshire coast, and by a line almost parallel on the north, from the Eden in Fifeshire to the neighbourhood of Dumbarton. It consists of several basins. The great deposits are those of Lanarkshire, Ayrshire, Mid-Lothian, and Fife. The central portions of the country are occupied by the under strata of the formation.—For an account of these see our articles on the Coal Formation of the Valley of the Clyde and Mid-Lothian.

England contains many coal-fields; the most important is that of Newcastle and Durham. The number of coal seams is stated by Messrs. Conybeare and Phillips to be forty; the two most valuable of which are the high chain and the low main, each about 6 feet thick, and distant about 60 fathoms from one another. The aggregate of coal is about 44 feet, but there are eleven beds too thin to be workable. The field is above 300 square miles in extent, and yields the chief supply of coal to the city of London. The coal supplies also all the eastern counties as far west as Hull, Boston, Peterborough, Bedford, and Windsor. About 6½ millions of tons are annually extracted from this great depository of coal; yet, it is calculated by Mr Bailey, in his survey of Durham, to yield for other 200 years a supply equal to the present consumpt. The Newcastle coal is of much superior quality to the common cubical or hard coal of the Scottish fields.

The other coal-fields north of the Trent are some detached fields in the north of Yorkshire; the coal-fields of South Yorkshire, Nottingham, and Derbyshire; the coal-field of North Stafford; the South Lancashire coal-field; the North Lancashire coal-field, and that of Whitehaven.

Those of the central coal district are the coal-fields of Ashby-de-la-Zouch, of Warwickshire, and South Stafford or Dudley.

The western coal districts are those of the isle of Anglesea, Flintshire, and Colebrookdale.

The south-western coal district contains the coal-fields of South Wales, the South Gloucester and Somerset basin, and the forest of Dean.

Our limits will not permit us to notice the extent and number of the various beds of coal which exist in these different fields. This we must reserve to our articles on the coal-fields of Great Britain. Nor can we do more than mention that coal is found in the following countries:—Belgium, France, Spain, Saxony, and other places in Germany, Sweden, and in Southern Russia and Greece. It occurs in China in immense abundance, in the Persian Gulf, in the districts of Bardwan, 130 miles from Calcutta, and in other parts of Hindostan.

The largest coal-field in the world occurs in the far-west of the United States of America. A coal-field also occurs in Virginia. Nova Scotia abounds in coal. It is found in Australia, New Zealand, and other parts of the world, almost always in basins, and alternating with sandstone and shale, containing traces of the same fossil vegetables which characterize the strata of Great Britain.

In our next chapter we shall give a description of the plants of the coal formation, and endeavour to elucidate more fully than we have been able to do in this, the history of a period, the products of which are of such importance to the human race.

## THEORY AND PRACTICE OF DYEING.

### CHAPTER VI.

#### MORDANTS.

Did each dye-drug impart its own colour to cloth, and did there exist a sufficient variety of these stuffs for the various shades of colours, dyeing would be a very simple art, as it would only be necessary to dissolve the dye-stuff and impregnate the goods. But so far from this being the case, if we except indigo, there is scarcely a dye-stuff that imparts its own colour to goods; nay the most part of the dye-drugs used have so weak an affinity for cotton goods especially, that they impart no colour sufficiently permanent to deserve the name of a dye. These circumstances render dyeing sufficiently intricate, and render it more dependent upon science; indeed, it is only by the nicest arrangement of a few chemical laws, that the dyer is enabled to turn to advantage the various colouring matters of which he is in possession. When the dyer finds that there is no affinity between the goods and any colouring substance which is put into his possession, he endeavours to find a third substance, which has a mutual attraction for the cloth and colouring matter, so that by combining this substance with the cloth, and then passing the cloth through the dying solution, the colouring matter combines with the substance which is upon the goods, and constitutes a dye. This third substance used, and which acts as an intermediate, combining two inimical bodies, is termed a mordant from the French *mordre*, which signifies, to bite, from an idea which the old dyers had that these substances bit or opened a passage into the fibres of the cloth, giving access to the colour. And although the theory of their action is now changed, the term is still continued, and perhaps further investigation will prove the term most applicable.

All the mordants, with one or two exceptions, are found among the metallic oxides. It may be supposed from this, that mordants are very numerous, but not so, for besides the necessity of them possessing a two-fold property—an attraction for both the goods and the colouring matter—they must also have the property of forming insoluble combinations, which property belongs almost wholly to insoluble bases; hence, we may perceive that the number of substances possessing all these properties is very limited.

The bases or oxides which are in general use and which appear to succeed best, are alumina, the oxides of tin, and iron; the first two are colourless, the peroxide of the latter is a light brown, and imparts to white goods a buff or nankeen colour, which in many cases affects, to a considerable extent, the colour of the cloth, a circumstance which must also be attended to by the dyer. Indeed, the principal part of all dyeing operations is the proper choice and application of mordants, there being a chemical union between them and the colouring matter; a new substance is formed, not only differing in properties, but differing in colour, from any of the originals; consequently, a very little alteration in the strength or quality of a mordant gives a decided alteration in the shade of colour. However, it gives the dyer a much wider field for variety of shades; at the same time a less number of colouring substances is required; as for example, logwood alone gives no colour to cotton worthy the name of a dye; yet by the judicious application of a few different kinds of mordants, all the shades from a French white to a violet; from a lavender to a purple; from a blue to a lilac; and from a slate to a black, are obtained from this substance.

Before any chemical union takes place between bodies, they must not only be in contact, but they must be reduced to their ultimate molecules; hence, mordants that are insoluble of themselves must be dissolved in some appropriate menstrua before their particles can combine either with the goods or the colouring matter. In doing this, the dyer must attend to the degree of affinity between the solvent and the mordant, to determine what force it will exert against the mordant combining with the fibres of the cloth; otherwise a powerful mordant may be weakened by the attraction of its solvent; as for example, common alum, even though much concentrated, is but a weak mordant for cotton goods, owing to the great attraction between the sulphuric acid and the alumina. But if acetic acid, which has comparatively a weak affinity for the alumina, be substituted for the sulphuric acid, it becomes a very powerful mordant. From these things having to be attended to, the dyer has many beautiful illustrations of the relative attraction of different substances for each other. In some cases the attractions are so nicely balanced that the mordant and colouring matter may be kept mixed, and the goods, when immersed in this solution, having a kind of reciprocal affinity, only receive their share; do not extract the colouring matter from the solvent, but the depth of colour upon the cloth corresponds with the colour of the solution. In other cases the attraction between the mordant and colouring matter is so powerful that, if the least quantity of the mordant solution be upon the cloth when put into the dye, it seizes the colouring matter which is instantly precipitated or rendered insoluble, and therefore unfit to combine with the goods, and what colouring matter may have combined with the cloth before being all precipitated, will be uneven; that is, the resulting colour will be light and dark. From these circumstances the reader will perceive the near alliance the art of dyeing has to the science of chemistry; but, an individual from experience may know these effects, and, though ignorant of the cause, may guard against these consequences; but knowledge, procured only by experience, is purchased at a very great cost, and attended with many unpleasant circumstances. When the solvent of any mordant has such a powerful affinity for the colouring matter as to cause it to precipitate before it combines with the cloth, the goods must be well washed from the mordant solution. When this is done, although the mordant which is in combination with the cloth be sufficient to extract all the colouring matter of the dyeing solution, the resulting colour is altogether impassible, being dull (without beauty), at the same time so liable to change with every circumstance, that it could not be dried. To make this a

little more plain we will detail a process. If a white piece of cotton be put through a dilute solution of chloride of tin, (red spirits,) and from this put through a weak decoction of logwood, the colouring matter of the wood will be immediately precipitated, changing its hue to a violet colour, very little of it combining with the cloth, and probably very unequally; but if the piece be thoroughly washed from the chloride of tin previous to putting into the logwood, the colouring matter of the wood will combine with the cloth, or rather the metallic base which is on the cloth; and, provided the logwood solution corresponds with the strength of the mordant, the liquor will be left colourless; but the piece will be a light brownish shade.* If a little of the chloride of tin be now added to the liquor, its effects upon the logwood will be the same as if the piece had been put into it without being washed, but with this difference, that the colouring matter is in combination with the cloth, upon which it is not only changed to a violet colour, but is rendered insoluble in water, and sufficiently permanent to constitute a dye. The substances thus added to the coloured liquor to change and fix the colours are termed *alterants*, in the technical language of the dyehouse *raising;* because it brightens the colour. Alterants and mordants are often spoken of as two distinct substances; but the only distinction is the mode of applying them. In some instances distinct substances are used. In the process detailed above, a little alum would do as well as the tin; or if a particular bluish shade were wanted, a little pyrolignite of alumina; but in almost all cases the mordant may also be used as the alterant. As to the preparation of the mordants and the proper choice of solvents for them, the manner of applying these mordants whether hot or cold, and the best means of fixing them, such as drying, &c., will be noticed under their separate heads, so far as our knowledge extends. In prosecution of this plan we will begin with

ALUM.—This is what chemists denominate a double salt, being composed of two sulphates—the sulphate of alumina, and the sulphate of potash. This salt has been known, and in general use among dyers, since the earliest accounts we have of their processes; but the true nature of its composition was not known till the present century. The alchymists knew that sulphuric acid was one of its constituents; and during the last century, it was discovered that the precipitate which falls down when the acid is neutralized by an alkali, is a particular kind of earth, which is called alumina. It has been since discovered that alumina is the oxide of a metal called aluminum, which can only be obtained by a tedious and somewhat expensive process. Amongst other peculiar properties of alumina, it has a strong attraction for organic matter, and withdraws it from solutions with such force, that, if the purest water be not used when preparing this substance, it will be discoloured; and when digested in solutions of vegetable colouring matters, provided the alumina be in sufficient quantity, it will carry down all the colouring matter from the liquid. By this means the pigments called lakes are formed; and it is this makes it so valuable as a mordant. The fibre of cotton, when charged with this earth, attracts and retains the same colouring matters.

Alumina is easily dissolved in sulphuric acid, forming the sulphate of alumina, which crystallizes with much difficulty; but this salt has a strong affinity for the sulphate of potash; so that when these two salts are mixed, or when a salt of potash is added to a strong solution of sulphate of alumina, they combine, and form common alum, which is easily crystallized. The preparation of British alum has been already referred to, when describing the manufacture of sulphate of iron.

A very pure alum is obtained in the Roman states from *alum stone*, a mineral which is continually produced at the Solfatara, near Naples, and other volcanic districts, by the joint action of sulphurous acid and oxygen upon some of the felspathic rocks. This mineral contains an insoluble subsulphate of alumina, with sulphate of potash; but it is partially decomposed by heat; so that, for the preparation of alum, the mineral is simply heated, till sulphurous acid begins to escape. It is then treated with water, by which process a very pure and excellent alum is procured—much superior to that manufactured in this country.

The alum manufactured in this country is almost always contaminated with sulphate of iron—a substance very deleterious to its use as a mordant. Iron may be detected by dissolving a little of the salt in distilled water, and adding a few drops of a solution of red prussiate of potash; or boiling a little, with the addition of a few drops of nitric acid, and adding yellow prussiate of potash. In both cases, a deep blue colour is produced, if iron be present. When the proportion of iron is considerable, it is better to reject the alum altogether, especially if there be any chance of using it for bright light shades. We have often experienced bad effects from the use of such alum upon light shades of drab and fawn colours, when dyeing to a particular pattern. Having obtained the particular shade, and adding a little alum as *raising*, the iron combined with the sumac upon the cloth, producing a colour two or three shades darker than required; leaving no other alternative but to take off the colour, and dye a-new—a process much more difficult, and the colour less brilliant, than at first. Alum is soluble in five parts of cold water, and in its own weight of boiling water.

The alum manufactured from the alum slate or shale, as we have already described (page 525), is a very weak mordant for cotton goods, owing to it containing an excess of sulphuric acid, which retains the alumina with great power; but if we neutralize a portion of the acid, so that no more will remain but what is necessary to hold the alumina in solution, which, according to experiment, requires only a third of the acid that is contained in common alum; this may be proved by taking a quantity of carbonate of soda, sufficient to neutralize the whole of the acid contained in a given portion of alum. Divide the soda solution into three equal portions, and add gradually to the aluminous solution, stirring all the time, two of these portions. It will be found that, although the alumina is at first precipitated, by keeping up the agitation for some time, the precipitate again dissolves, forming an alum containing only a third of the acid of common alum. In this state, alum is a very powerful mordant for cotton, as the base is held more feebly by the sulphuric acid, and is readily detached by the superior affinity of the cloth to form a mordant. Alum in this state is known by the name of cubical or basic alum, from the form in which it crystallizes. We have already referred to Roman alum being superior to other alums. For a long time, the dyers considered this superiority to be wholly owing to its purity; and it is only within these few years that chemists have found that it is of the same composition as the cubical alum.

The most common, and, we believe, the best, method of using alumina as a mordant, is by substituting acetic acid for sulphuric acid as its solvent. The acetate of alumina has several advantages over the sulphate: 1st, the acetic acid possesses some analogous properties with alumina, in its action upon the vegetable colouring matter; 2d, it holds the alumina with much less force than the sulphuric, and consequently yields it much easier to the cloth; and 3d, being volatile, a great portion of the acid flies off during the process of drying. When strong colours are wanted, and the mordant is of such a nature as will admit of being dried, it is better to dry from the mordant previous to dyeing. This last property of acetic acid is very convenient, as it frees the cloth from any superfluous acid which may have been in the mordant; besides, it has been found that during the drying, by heat, the soluble acetate is converted into a subacetate still more insoluble —and be it observed, high solubility is another very important qualification of a mordant. We may here put our brethren in mind that when goods containing volatile acids are drying, no other goods should be allowed to be in the same apartment, as the acid will combine with them, and will affect almost any colour that either is or may be afterwards put upon them. Many unpleasant and also expensive consequences occur from the neglect of these matters.

During the various applications of these aluminous mordants, and the manipulation attending them, many curious and interesting chemical phenomena are witnessed by the dyer. Although his familiarity with them prevents altogether any particular remark, we shall instance one or two of those, attendant upon the process of dyeing madder reds, by means of acetate of alumina. This process, however, is more immediately connected with calico printing, while our particular object in these essays is dyeing to be finished as such. The cloth to be dyed is first thoroughly bleached and dried, it is then padded, or soaked in acetate of alumina about the specific gravity of 40° (8. Twaddell), and passed at full breadth through *nipping* rollers (squeezers). These are large rollers covered with cloth, which revolve one upon another. The pressure upon the piece, as it passes through for the purpose we are describing, ought to be such that

* Why the metallic base is on the cloth after being washed, will be explained under TIN.

it will dry in five minutes, passing over rollers in a stove heated to 160° Fah. After being dried, the goods are passed through a dung bath, made up with about one part cow's dung to fifty parts water, at a heat of 130° Fah.; from this they are well washed through the dash-wheel. Into a boiler of cold water is put from one to three pounds of madder, according to the colour wanted, for every pound of cloth. The cloth is put in, and a fire is kindled under the boiler, and so regulated that it will boil in two hours, during which the cloth is kept running over a *winch* or wheel, first the one direction and then the other, and kept spread as much as possible, so that the whole surface may be equally exposed to the dyeing operation. The boiler is kept at the boil from twenty to thirty minutes; this, with washing first through bran, and then water, completes the dyeing operation. If a white pattern be wanted upon these reds, the pattern is printed upon the goods with citric acid, (about 25° of Twaddell, thickened with pipe clay and gum)—about twelve or twenty-four hours* after being dried from the mordant. This decomposes the aluminous mordant upon these parts, so that no dye adheres to them afterwards. Now, from a difference in the manipulation, or a little variation upon some of these processes, several curious changes take place upon the mordant. For example, were the pieces merely washed with water from the mordant, previous to printing on the resist acid, although the treatment be every way else the same, the discharge of the mordant is not effected, these parts upon which the citric acid is printed will be scarcely observable after the cloth is dyed, while in the other case they are perfectly white.

A somewhat similar result, in reference to the action of the discharge acid, takes place, if the heat of the stove in which the goods are dried from the mordant exceeds a certain temperature, or if dried upon steam rollers.† No acid, printed upon the cloth after this, will produce a white, except it be of a strength that will destroy the fabric of the goods: besides this, the colours afterwards dyed upon mordants heated in this manner, are extremely bad, being heavy and dull.

Various opinions have been offered by practical men upon the probable cause of these changes: some suppose that by the excess of heat, the acetate of alumina is altogether decomposed, the acetic acid flying off, and the alumina left in union with the goods, which adheres with such an affinity that it requires a stronger acid than the cloth will bear to disengage it; but from the similarity of the effects which take place by merely washing the piece from the mordant, this opinion is liable to objection, for the sub-acetate of alumina is not decomposed by washing with water; however, different causes may produce the same effects. If the above opinion be correct, the circumstance of a bad colour resulting from the acetate being decomposed, it will follow that it is not the alumina alone which constitutes a mordant, but its salt; in this case, it is the sub-acetate of alumina—the acetic acid being an essential ingredient to the dyeing process. This we are inclined to believe, for in those mordants, as we have already stated, where the acid can be separated by washing, the proper colour is not produced until some salt or acid be added to the colouring matter as an alterant. It is supposed by some writers that the dunging and washing extracts the acid from the mordant, and leaves the base upon the cloth. This we conceive to be an error; for, although the part which dung acts in these processes is not well understood, yet from the analysis of this substance, and the nature of the salts which are supposed to be useful in these operations, there is no probability of the aluminous salt being decomposed. One principal use of the dung bath is to combine with and carry off any loose or supernatant mordant which may be upon the cloth, not combined, and which might affect the colour, or more particularly, the parts wanted white.

* It is of the utmost consequence that the goods be thoroughly cooled previous to printing on the resist, otherwise there is danger of it not being successful. Pieces mordanted with acetate of alumina, and dried at a great heat, are highly charged with electricity. If the hand be suddenly drawn along the piece, a complete shower of fire is observed, with a sharp cracking noise—at the same time a prickling sensation is felt. Whether this has any effect upon the mordant, in its immediately combining with other substances, we do not know, but cloth in this state is very ill to moisten: water runs off it as off a duck's wing, but as yet we offer no explanation, our researches not being complete.

† Large metal cylinders into which steam is admitted, and the cloth passed over the surface.

The acetate of alumina is easily prepared by mixing a solution of acetate of barytes, lime or lead with alum. When any of these salts are added to alum, a double decomposition takes place; the sulphuric acid of the alum combines with the base of the salt which falls to the bottom; the acetic acid unites with the alumina, forming acetate of alumina, which remains in solution, mixed with the sulphate of potash which formed a constituent of the alum. The acetate of lead is the salt generally used for this purpose in the dyehouse; the proportions of the lead and alum vary according to the nature of the colour to be dyed, and the peculiar taste of the dyer, for the preparation of this substance, is one of those operations which every one who practises it thinks he has the best method, but so far as we have had an opportunity of knowing, the superiority only existed in the mind of the individual, or rather in its being kept secret.

The following method we have found to answer very well for general use. Into a boiler or pot put 20 lbs. of crystallized alum with about nine gallons water, and boil till the alum is completely dissolved. In a separate vessel dissolve 20 lbs. of acetate of lead in about three gallons of boiling water. This is added to the alum while at a boiling heat, and well stirred. The sulphuric acid combines with the lead, forming an insoluble sulphate of lead which falls to the bottom as a heavy white precipitate—the acetate of alumina forms the clear liquor. The difference in the preparation of this mordant is in the proportion of lead varying from one half of the alum to equal weights. There is also added to the alum and lead a quantity of carbonate of soda varying from four to eight ounces to the five pounds of alum. This is added for the purpose of neutralizing any excess of acid which may be present; but there are many dyers who will not use soda or any other alkaline substance when light bright shades are wanted, under the impression that the colour is much brighter without alkalis, but the difference of hue is hardly perceptible. Some use lime; soda, however, is best—without soda or some other alkaline substance, the mordant is not so effective. There are also some who object to the use of soda, as it throws down the alumina; but we have already noticed under cubical alum, that a very little acid holds the alumina in solution; so that although soda, when added to the acetate of alumina, appears to precipitate the alumina, by a little agitation the precipitate is again dissolved, forming a mordant better adapted for strength of colour. From the following recipes it will be observed, that the qualities of the aluminous mordants are similar both in England and France:—

| | |
|---|---|
| 100 pots boiling water,<br>100 pounds alum,<br>100 pounds acetate of lead,<br>10 pounds crystallized soda. | This mordant is best adapted for reds. |
| 100 pots boiling water,<br>100 pounds alum,<br>50 pounds acetate of lead,<br>6 pounds soda. | This is best for bright yellows. |

In addition to the above, Dr Ure in his Dictionary of the Arts and Manufactures, article "Calico-Printing," gives another proportion:—

50 gallons boiling water.
100 pounds alum.
75 pounds acetate of lead.
10 pounds soda.

The following curious phenomenon was observed by Gay Lussac, viz., that the solution of a pure salt of the acetate of alumina may be boiled without decomposition; but if sulphate of potash, or any other neutral salt of an alkali be present, the solution becomes turbid when heated, and a basic salt precipitates, which dissolves again on cooling. Now the acetate of alumina, prepared from the common alum, always contains sulphate of potash. If by the presence of this salt a portion of the acetate of alumina be thrown down when hot, and being incorporated with the sulphate of lead, which falls in a very dense state, it may there be lost to the dyer. Whether this be so we know not, as we have not, since we knew of this phenomenon, had an opportunity of putting it to the test; but it would be advisable to stir the whole after becoming cold, that if any of this basic salt should be bound up with the precipitate, it might be set at liberty and dissolved; but it must be borne in mind, that if this be stirred when cold, it takes a long time to settle.

The most of the acetate of alumina used in dyeing, is prepared from pyroligneous acid, and is called by calico-printers *red liquor*, but by dyers *mordant*. No other substance, whatever be its nature, is distinguished as mordant. The pyroligneous acid is one of the products of the destructive distillation of woods. The hard woods, such as oak, ash, birch, and beech, alone are used; they are put into large cast-iron cylinders, so constructed that a fire plays about them, so as to keep them at a red heat, having openings through which all volatile matter escapes by pipes, which lead into condensing vats. The matters thus obtained consist principally of pyroligneous acid, mixed with a black tarry matter, having a very strong smell, from which the acid had its name, although it has been long since known that it is simply acetic acid (vinegar.) There is a great variety of other substances present, some of which have very singular properties, and some of the continental chemists suppose, they might be made available in dyeing. The products of the distillation of the woods are allowed to stand for some time, after which as much of the tarry matter as swims is skimmed off; the remainder is filtered, after which it is put into a boiler and heated a little, and lime added by degrees, till the acid is neutralized; then a quantity of lime is added in excess; the whole is then made to boil; this throws up the tarry matter to the top, where it is taken off; when it is purified as much as it will by this means it is syphoned off into another boiler, and a quantity of alum added; the acetate of lime, the sulphate of alumina and potash, mutually decompose each other; the sulphate of lime falls to the bottom; and the acetate of alumina remains in solution, which, when sent to the dyers, has generally a specific gravity of 1·90 (18 Twaddell). It has a dark brown colour, and a very strong pyromatic odour. When the acetic acid is wanted pure, it passes through a number of other processes which do not come within our province to describe in this place.

## IRON FOUNDING.

### SECTION IV.

Loam-moulding, the last branch of the art, as it has been treated in these papers, falls to be discussed in the present article. As already described, the peculiar functions of the loam-moulder is to construct loam patterns and mouldings of certain cast-iron work, by which the mould may be formed without incurring the expense of the construction of a wood pattern for that purpose. In many cases, also, the loam-moulder constructs moulds for which wood patterns could not be provided. The economical employment, however, of loam as a substitute for wood patterns and sand, is restricted, in general, to the manufacture of the more regularly shaped work of a foundery. Every variety of circular bodies may be done in loam: large square vessels, too, are done by the same process.

Every piece of loam-moulding, of any considerable extent, is a regularly built structure, being composed of bricks, arranged in layers, and bedded in loam, in which they are also entirely enveloped, particularly on those sides contiguous to the mould. The composition of loam demands strict attention, varied, as it requires to be, suitably to the various applications of loam. Two indispensable qualities are those of firmness and porosity. The first is evidently necessary, considering the very great hydrostatic pressure to which, in large castings, mouldings are subjected, while the iron is liquid. And again, the copious effusion of gases from the mould, arising from the action of the heat of the cast, renders it absolutely necessary to provide for their escape through the material of the mould. This is provided for in the porosity of the mass, which must therefore be in such a degree as to offer a transit sufficiently free to the airs evolved, while the mould is impervious to the metallic fluid.

To fulfil these conditions, the materials of loam are principally clay and clean sharp sand. These elements are opposed in their nature, and operate as counteractives. The clay is the binding element, from which the loam derives its firmness: the sand, intermixed with it, modulates its closeness, and renders the loam open in the grain. Thus, both these elements are essential in the composition of the substance. Cow-hair, also, obtained from hides of cattle by tanning, is mixed in loam: it answers two purposes. In the first instance, while the raw loam is being moulded into the form desired, the hair assists the tenacity of the parts of the loam, which is often largely charged with water. Again, when loam work is baked in the stone, which, for cores, is raised to the greatest attainable temperature, the hair is burnt out of the loam, and of course leaves its own empty track. The mould is thus perforated in all directions, throughout, by these artificial sinuosities; and in this way the openness of the mould is very much increased. Mill-seeds, sawdust, horse-dung, and straw, especially the last, are also extensively used in the formation of loam cores. It ought to be understood that loam cores must be completely dried and burnt before they can be serviceable; the object being, to anticipate the work of the hot iron with which they must afterwards come in contact, by expelling completely their humidity, and the occasional gases originated by the burning of their combustible matter. Were this precaution not taken, particularly for cores much confined, they would inevitably be broken up by the sudden generation of confined air, which could not escape as suddenly. It may be as well to state here that the general results of the action of melted iron on the mould are carbonic acid, and oxide, and carburetted hydrogen. In the first place, the carbon constituting the blackening used in all moulds, and the coal powder in green sand moulds, seizes and combines with the oxygen of the aqueous particles in the neighbourhood, forming a mixture of carbonic acid and oxide; the hydrogen of the water thus let loose combines with another portion of carbon, producing carburetted hydrogen, which, with the carbonic oxide, burns with a bluish yellow flame on coming in contact with the external atmosphere.

For all varieties of circular bodies, or such as may be described round one axis, a wooden board is cut on one edge to the exact form of the object, being, in fact, a half skeleton of its outline. If the body be cored out, a board must also be provided, cut to the form of the interior space. A central spindle is erected, which is to represent the centre of the body to be moulded; to this spindle one or more arms are screwed, provided with glands, by which the *loam-board*, as it is termed, is set at the proper radial distance from the centre, and firmly fixed to it. The whole being in this condition turned round the centre, it is obvious that the figure of the body will be described. With this general idea, we shall proceed to particular description.

Sugar pans are among the most familiar examples of loam casts, and, as they are in themselves instructive specimens of this kind of work, they shall be selected as our first illustration.

Fig. 1 is a general view of a Carron-shaped sugar pan. The portion *a b*, constituting the pan, is a simple spherical cone, and *b c* is the brim.

The pan is moulded and cast in an inverted position, similarly to the Irish pots already described. In the first place, then, a cast-iron ring *a a* (fig. 6.) is levelled upon blocks, which raise it off the floor of the foundery, and is placed concentric with a spindle *b*, which stands upright, being placed at the under end in a cast-iron step sunk in the floor, and stayed at the upper end in a bush on the end of a bracket *c*, which projects from the wall, and turns horizontally upon pivots. The spindle thus stayed is free to move round in both directions. To prevent the bracket from moving on its pivots, it is linked by the extremity to the wall. A forked arm *d* is fixed upon the spindle by an eye at one end, tightened by a pinching screw. Between the branches of this arm the loam board *e* is set, and fixed by glands in the required position.

Fig. 1.

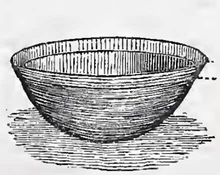


Fig 2.

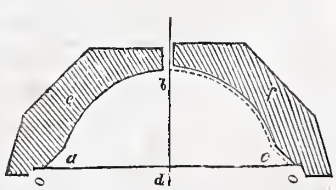
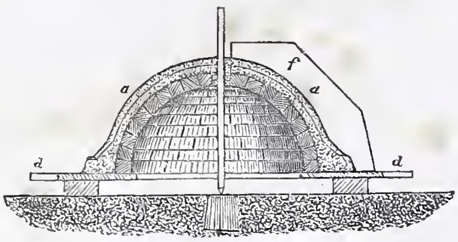


Fig. 2 represents the outlines to which the loam-boards are cut; *a b c* is the figure of the interior surface of the pan, *b d* being the axis. A board *e* is in the first place cut to the semi-outline of the interior; and, further, has an additional check *o*, which turns out a corresponding knee in the mould, the object of which is to support the overlying part of the mould on its horizontal surface, and to act afterwards by its vertical surface

as a guide in replacing the mould. Another board, *f*, is, in the same way, cut to the external figure of the pan, with a check precisely similar to the one in the board *e*; and thus it will act as a guide in setting the second board.

Fig. 3 is a vertical section of the work in the first stage of its progress. Upon the ring, *a c*, a kind of dome, *b b*, is, in the first place, built of bricks and loam, generally four inches thick. The moulder is guided in the construction of this dome by the interior loam-board, sustained by the spindle. The external surface ought to be everywhere about two inches distant from the surface described by the board, *e e*. Before building up the dome to the crown, coals are placed on the floor within it, which are afterwards kindled for drying

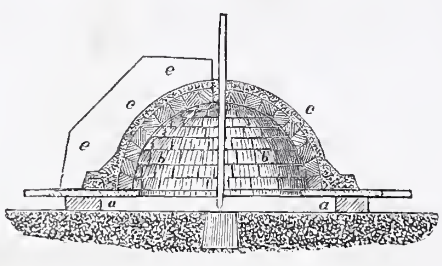
Fig. 3.




the work. The crown is then nearly completed, leaving only a small space round the spindle to allow of ventilation when the combustion within is going on. By this aperture the moulder is enabled to manage his fire, so as to check its progress, if necessary. The consumption ought to be very slow, so as to allow of the heat taking effect upon the entire mass.

Over the brick dome a pasty layer of core loam, *c c*, is applied; for it is, in fact, the core that is now being formed. The surface is finished off by a smooth coating of wet loam, the redundancies all over the surface being swept off by the board in its revolution. Upon this surface the inside of the sugar pan is cast. The fire is now kindled, and, as the surface of the mould becomes dry, it is painted over by a brush with a mixture of water and charcoal powder, with a little clay additional. This operation prevents adhesion between the surfaces of the core and the coat of loam applied to it.

Fig. 4.

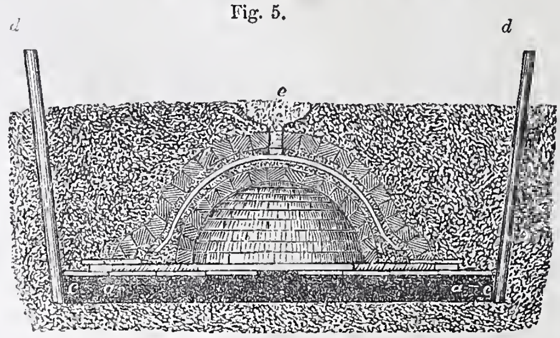



The core-board having been removed, it is replaced, as in fig. 4, by the thickness-board, *f*, (fig. 2,) of which the edge describes the external surface of the pan; and, as already remarked, simply rubs against the knee formed round the base of the core. Another layer of loam, *a a*, is then spread over the core, and is rounded off properly by the board, similarly to the core itself. This "thickness," it is evident, is the exact model of the pan itself. When well dried, it is blackwashed, as was done to the core. The upright spindle is now removed, leaving the small vent-hole through which it passed to promote the complete combustion of the coal. There is now laid horizontally upon the ears of the platform, *d d*, (fig. 4,) another similar platform like the former, but sufficiently large to pass over the moulding already executed. A new layer of loam, two inches thick, is laid over the thickness, and smoothed by hand. Then, upon the second platform a brick vault is constructed as before, of which the inner surface applies to the new coat of loam. This contracts a strong adherence with the bricks, which absorb a part of its moisture, while the coat of paint prevents its adhesion to the thickness. The brick and loam covering are named the cope.

The structure is now completed, so far as the formation of it is concerned. The whole mass must now be thoroughly baked by the continuance of the fire. Stoves are preferred to internal fires, when they are large enough to receive the work. The intense heat, however, necessary to the preparation of many cores placed in confined parts of moulds, is not essential to such cores as the above described, where there is so free space within it for the escape of air.

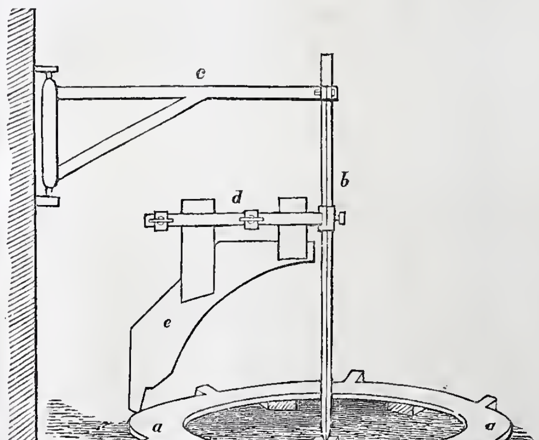
Cast-iron bars may be substituted for the brick forming the cope. These "irons" must, of course, have the curved form of the dome to which they apply, being arranged so as to converge towards the crown. They are simply run off in open sand, when required, with snugs cast upon them, by which the cope may be lifted off. They are bedded in the external coat of loam, which is smoothed over them, and bound together by wires and bands of hoop-iron.

Fig. 5.




The next step is to lift off the cope, which is done with the assistance of a crane. This being done, access is had to the interior, and the thickness is easily broken away without any injury to the mould; this thickness being, in fact, the pattern of the pan, it is evident that, when the cope is replaced exactly, which may be done by the guidance of the knee before described, there will be a space within to be filled by metal, being the true form of the pan. Before replacing the cope, the vent aperture in the core is filled up and smoothed over, though the one in the cope is left open to serve afterwards as a gate for the reception of the metal.

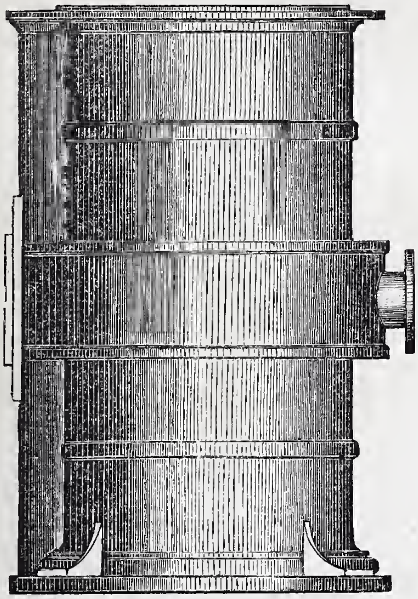
Fig. 6.




The cope being reset, and clamped firmly to the core by double knees and wedges embracing the rings, the whole is removed to the pit, in which it is sunk and rammed up tightly with sand by iron rammers, which are managed by half a dozen or more men, who walk regularly round the moulds, keeping time with their rammers, and dealing heavy and light blows alternately, while one or two workmen above shovel in additional sand as required. Fig. 5 is a vertical section of the pit, showing the manner in which it is arranged. A space sufficiently deep is first cleared out, and across

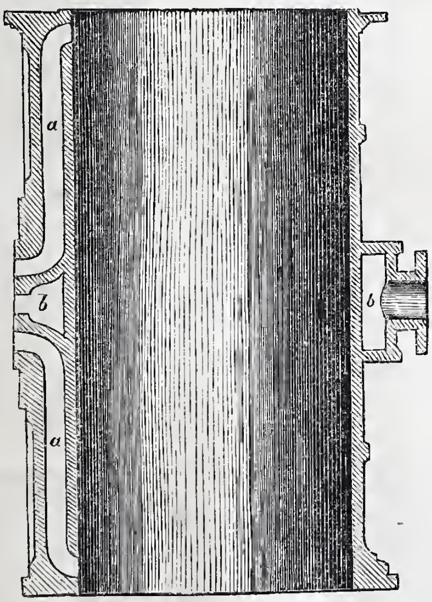
the bottom a passage, *a a*, is cut, and overlaid with plates, having only an open part at the centre, which connects it with the interior space, *b*, in the mould. Two pipes, *c d*, *c d*, are next laid in against the sides of the pit, communicating with the channel, *a a*. When the mould is lowered into its position in the centre, as indicated, and

Fig. 7.



the sand rammed about it in the way already described, an oblong shallow trough-like cavity, *e*, is formed in the surface of the sand, one end of which opens into the gate hole of the mould, which is closed by a pin while the ramming is proceeded with.

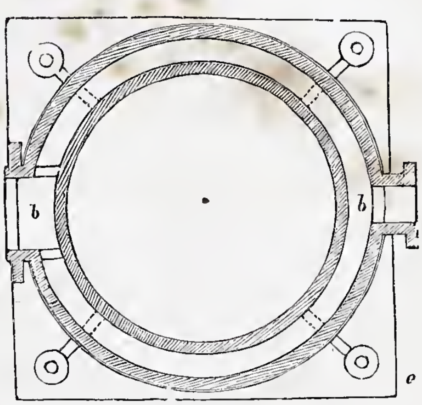
Fig. 8.




The channel, *a a*, and the pipes, fulfil the very important purpose of venting the air confined in the hollow space, *b*, together with what is forced through the substance of the core when the metal is poured. Now, as a large quantity of inflammable gas is driven off, its union with the atmospheric air in the chambers below, forms a dangerous explosive mixture, which, rushing out at the openings, *d d*, might be inflamed by accident, and, if not prevented, would blow up the whole work with irresistible force. To prevent such an occurrence, the vents are stopped at *d d* with plugs of straw or mill waste, or simply covered with pieces of fine wire sieve; the gas passing through these substances before being exposed to accidental inflammation, security from explosion is rendered certain, as flame cannot pass through their interstices. The principle alluded to is familiar to all as exemplified in the Davy lamp, in which the flame in the interior is intercepted by a wire gauze medium.

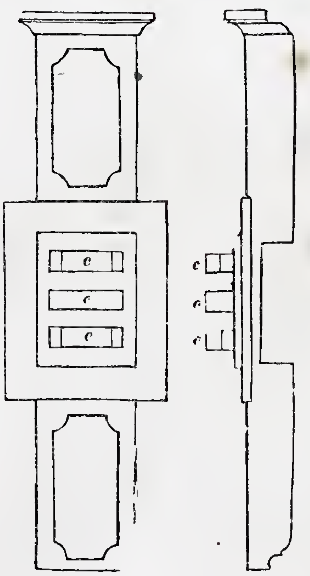
When the metal has been poured, and has well set, the casting is cleared out as quickly as possible, as, on account of the contraction it undergoes, it is apt to jam upon the core. Confined cores are always broken up as soon after casting as may be, especially when their form is calculated to resist great compressive force.

Fig. 9.




When the object to be moulded presents more complicated forms than the one now chosen for the sake of illustration, it is always by analogous processes that the workman constructs his loam-moulds, but his sagacity must hit upon modes of executing many things which, at first sight, appear to be scarcely possible. Thus, when the

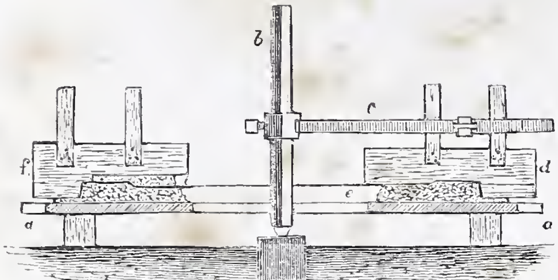
Fig. 10.




forms of the interior and exterior do not permit the moulds to be separated in two pieces, it is divided into several, which are nicely fitted with adjusting pins. More than two cast-iron rings or platforms are sometimes necessary. When oval or angular surfaces are to be traced, instead of those of revolution, no upright spindle is

employed, but wooden or cast-iron guides made on purpose, along which the pattern cut-out board is slid, according to the drawing of the piece. In addition to brick-work, iron wires or claws are often interspersed through the work to increase its adhesion. When parts of a mould are higher than that portion immediately under the gate, flow-gates are usually adapted to such parts, by which they may be relieved of the impurities that would be apt to lodge there. Such a

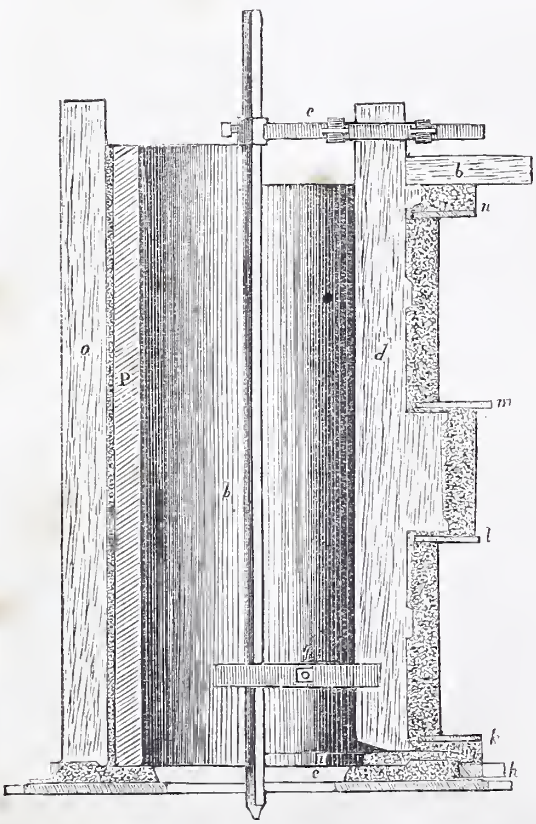
Fig. 11.



case is that of a flattish-bottomed boiler, of which the bottom is hollow externally.

Our second example of loam-mouldings shall be that of the steam-cylinder of an ordinary high-pressure engine. Fig. 7 is a side elevation of one; fig. 8 is a sectional elevation; fig. 9 represents a horizontal section, taken through the centre of the exhaust steam-

Fig. 12.

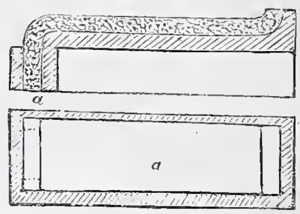


passage; *a a* are the steam passages to the cylinder; *b b* the exhaust passage, all uniting in the face, *c*; *d* is the outlet from the passage, *b b*.

It is to be noted, that the body of the cylinder is round, while the base or bottom flange, *e e*, is square, and the face, *f c f*, containing the steam-ways, is supplementary to the main part, as also the stiffening feathers for strengthening the base. For these parts, then, patterns in wood are made, adapted to fit the loam work. Fig. 10 is front and side views of the pattern of the part, *f f*, having core prints, *c c c*, for the usual purpose of steadying the cores.

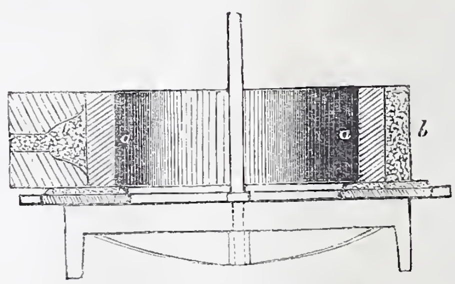
As the upper flange of a cylinder, such as the one now described, is generally smaller than the under one, and more exposed to view, the cylinder is usually cast in an inverted position, to have the former flange solid. According to the method now most generally adopted for moulding cylinders, the cope or external outline is formed in the first place, by an interior loam-board cut to the form on the

Fig. 13.



outer edge. Thus, the cope is first constructed, after which it is removed, and, on the same centre, the core or interior outline is formed by an external loam-board, cut on the inner edge. If, now, the cope be replaced concentric with the core, they will include between them a vacant space, being the exact figure of the cylinder. Fig. 11 represents the two first stages of the work; the core ring, *a a*, seen in section, being of the dimensions necessary for the work, is first laid down, concentric with the spindle, *b*, and levelled off the ground upon blocks. To the arm, *c*, projecting from the spindle, the loom-board, *d*, is fixed, by glands embracing two arms nailed

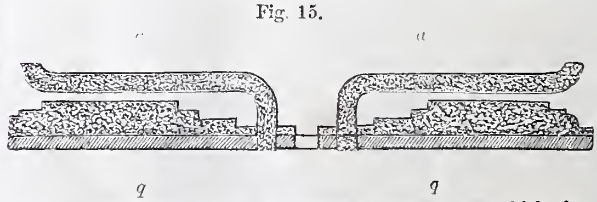
Fig. 14.



upon it. This board is cut to form the bearing, *e*, of brick and loam for the core, the bearing acting, also, by its sloping edge, as a guard in closing the mould.

Its upper surface now forms the lower side of the cylinder flange. The board is now altered, as expressed at *f*, on the opposite side, so as to form the flange, *i*, which is made simply of loam. This is the second stage of the work, and the flange must be dried like the bearing before it, to prepare for the next stage. It is necessary to

Fig. 15.



form the flange singly, to be an additional bearing upon which the superstructure is founded. It it were cut at once out of the cope, the overhanging loom must give way.

The arm, *c*, is now shifted up along the spindle sufficiently high for the next operation, represented at fig. 12. A loam-board, *d*, is cut to the form of that part of the cylinder included between the extreme flanges—these themselves, as we have

stated, being made of loam and wood. The board includes the exterior outline of the circular exhaust-passage; and it will be seen that, when set in motion, it touches the flange at the bottom, and a horizontal piece *b* projects from it to the top to sweep a flat surface on the cope upon which the square flange is to be laid. The arm *c* is assisted in holding the board by two pieces of iron *f* at the bottom, screwed together upon the spindle and the board, the cope ring *h* having been laid down upon the core ring *a a*, surrounding the bearing *e*, with a little space between them. The steam-way pattern, fig. 10, is set in its place in an inverted position, resting on the flange *i*. Its precise position will be ascertained by the loam board, which ought to touch it when passed round. The building is commenced upon the cope ring; and, having been raised above the flange *i*, another ring *k* is bedded on the building, lying near into the loam board, with a segment cut out of it sufficient to clear the steam-way pattern on both sides. Upon this ring the building is continued till near the under side of the exhaust-passage, at which place a similar ring *l* is bedded on the structure, overhanging it

*Fig.* 16.


sufficiently to sustain the building round the passage, at which place it is greater in diameter. Having built up the height of the passage indicated by the board, a layer of loam on the top is swept flush with the upper side of the projection by means of a transverse stick nailed on the board. This forms a parting surface by which the cope is divided into two parts, the necessity of which is apparent on considering the method of placing the cores for the exhaust-passage. After blackwashing the surface, a third ring *m*, with projecting snugs on its rim, is laid over it, being faced, however, with a layer of loam to protect it from the melted iron. The building is continued upon this plate till it reaches the top, when it is succeeded by another plate *n*, of a square external form, and somewhat larger than the square base plate of the casting immediately over it. The building is finally carried up to the horizontal piece *b*, which smooths off the upper surface with loam.

It will be remembered that the mould is on one side, cut longitudinally throughout by the pattern of the steam-ways. On that side, therefore, it has to be completed; this object is attained by providing a cast iron plate, done in open sand, fitting generally the interior of the pattern, and having three openings through which the core prints are passed when the plate is applied. It is daubed all over the inner face, with stiff loam, and being set up in its place, the loam receives the impression of the face of the pattern. Lastly, the square flange pattern is laid over the whole, upon the bed prepared for it; preceded by the four stiffening flanges, and is surrounded with additional loam, flush with its upper side, to form a bearing for the top plate.

In the manner thus described, the external figure of the cylinder is formed. The whole mould from the bottom is lifted by the snugs on the cope ring *h*, off the core ring, upon which the two layers, *e* and *i*, are left. It is conveyed to a sufficient stove to be thoroughly dried.

This is an operation comparatively simple, as the core is but a simple cylinder of brick and loam. In the first place, as the loam flange *i* has formed its impression on the interior mould under the plate *k*, it is of no further use, and is therefore broken away, leaving the bearing clean to receive the core, as represented on the left side of figure 12; *o* is the loam-board in its proper position for working, having its inner edge set parallel to the spindle, and to the diameter of the cylinder required, and simply fixed to the arm at the top. A cylinder of brick work *p*, is first built up, being everywhere an inch or so clear of the board. A coat of loam *s* is next laid on as usual, to fill up the clearance and complete the core. The board and the spindle being removed, the work is lifted away to the stove, on the core ring *a a* by the snugs upon its rim.

The next business of the moulder is the formation of the smaller cores, which are to form the winding steam passages to the cylinder, of which there are three; the two supply-passages *a a* and the exhaust-passage *b*. The two former being of the same shape may be formed from one core box, seen in plan and section at fig. 6, in which *a* indicates the core boxes; for such kinds of cores are usually formed on three sides, and open on the fourth side to admit the material, which is shaped off on this side, by the edge of a piece of wood cut to the contour of the core, and drawn along upon the sides of the core-box as guides. The core for the exhausting way is partly circular, and partly otherwise at the ends. Its formation is thus more complicated than that of the other cores. It is made in three parts; the centre part annular to embrace the cylinder, and formed by a loam-board, and the terminations made in core-boxes, and fitted to the other fig. 14 is a vertical view of the method of making the annular core. It is built upon a portable square table convenient for small circular work generally, as it may be conveyed to the stove without the necessity of shifting the centre. The spindle turns by a conical pivot on its under end moving in a socket, which is the only staying it requires. A block *a a*, is first prepared, being a plain built ring of which the exterior is smoothed with loam, and is made exactly to the interior diameter of the core and to the same depth. The core seen in section at *b* is run upon the outside of the block to the necessary thickness, in the course of which two wrought-iron angular rods are imbedded in the core to impart their stiffness to it. At *b'* is shown the valve face portion of the core (at *c*, fig. 8), of which *c* is the box for making it in section. The round core for the short straight passage *d*, fig. 16, is made of loam, being run up on a short iron centre.

In the making of these small cores, as in that of green sand, it is necessary that they be strengthened with iron rods bent to their form, so as to pass through the heart of them, and finished with eyes at the outer extremities, for locking them to the face-plate. An open passage, running through each core, is formed, as in green sand cores, by laying pieces of cord along the irons. These passages are of great importance, as upon them depends the escape, through the openings in the face-plate, of the otherwise confined air existing in the mould, while the metal is being run. The too close proximity of these passages at any point to the surface of the cores must be well guarded against. In such a case, the melted metal in contact with the core breaks into the interior of it, and intercepts the air in its escape, which aggravates the evil, by forcing it into the body of the metal, and thus rendering the casting unsolid. The accident even assumes, in some cases, a more serious aspect, by causing such an agitation in the metal as to render the cast utterly useless; indeed, we have even seen the metal already poured, almost wholly expelled from the mould, and sent in showers through the foundery, the occurrence being entirely attributable to an oversight of the nature referred to.

Fig. 15 is a side view, in section, of the mode of placing and fixing the cores *a a*, for the steam-ways to the cylinder; *q q*, is

the face-plate lined with stiff loam, which retains the impression of the steam-way pattern ; *a a*, are the two cores, the nearer ends of which are passed through the openings made in the plate for them, and fixed there by small rods passed through the eyes of the stiffening irons. The ends are made with shoulders which bear upon the upper side of the plate, fig. 15, which may be understood from the form of the prints in fig. 10. The horizontal parts of the cores *a a*, fig. 15, are supported at their proper distance off the loam work beneath them, by steeples stuck into it.

The mould and the cores having been well dried, they are dressed and smoothed where necessary, and finished with a coat of coal powder. Fig. 16, is a vertical section of the whole mould, showing all the parts fitted to one another, so as to contain among themselves the vacant space indicated by a white ground, into which the metal is delivered. The mode of depositing and putting together the mould is as follows ; the main core *p p* is lowered upon its rings, from which it is never separated, into a pit dug in the floor of the foundery, sufficiently deep to receive the core below the surface. The exhaust-passage core, is next deposited in its exact position in its place on the top of the lower part of the cope, being sustained in the usual manner off the core by chaplets made of two pieces of strong hoop iron, rivetted on the ends of two studs, so as to have the necessary thickness of space. The lower part of the cope thus furnished, is next lowered over the main core into its place upon the core ring, thus surrounding the core, and containing with it a space between as indicated in the figure. Another set of chaplets are deposited upon the exhaust core, which, by being in contact with the upper half of the cope when placed above, prevent the core from floating off its seat when immersed in the fluid metal. This is a matter of greater moment than the sustaining of the core from below, as will be apparent on considering the great difference of specific gravities of dry loam and iron. In this case the upward effective pressure of the fluid metal upon the core is proportional to the difference of their specific gravities, which being so much in favour of iron, the pressure upwards, sustained by the chaplets, cannot be much less than the weight of a body of iron of the same bulk as the core. Therefore, as a safe general rule, chaplets are or ought to be made of sufficient strength to resist the weight of a body of iron equal in bulk to the core, for the support of which they are destined.

The upper part of the cope having been let down into its place ; the face plate with its cores fixed to it, fig. 15, is let down in front of the vacancy in the side of the cope, till it arrive at the proper height, when it is set close into its place, and the end of the exhaust core *b* receives *d* through the middle opening in the plate, and secured on the outside by the eye. The branch core *d* is then set in and supported on chaplets, and over it a ring or cake of loam *m l*, seen in section in the figure, is placed, being strengthened internally with iron, like the cores. Thus the cake of loam forms by its inner surface the outer surface of the flange.

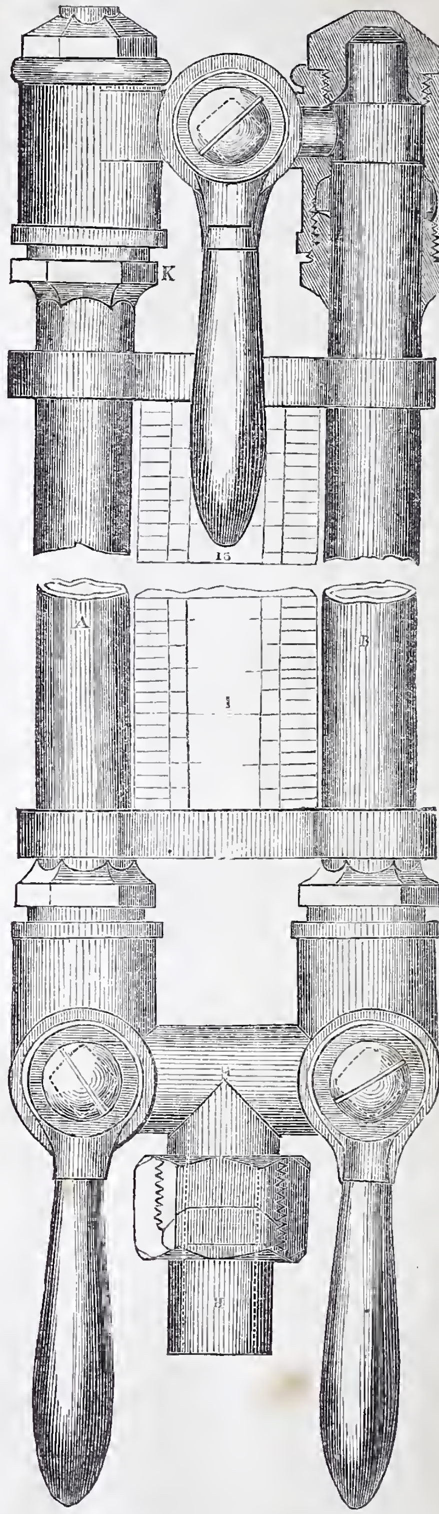
The mould being all finished below the top, the pit sand is rammed tightly round it to enable it to withstand the pressure of the metal, air-vents being provided in a manner similar to those for the sugar-pan mould already described. The top plate *r r* is laid on lastly, holes being provided in it for the admission of the metal. It is covered in with sand, through which passages are led up to form the holes to the external surface as runners.

## MARINE SALINOMETER,

### FOR INDICATING THE DENSITY OF BRINE IN THE BOILERS OF MARINE STEAM-ENGINES.

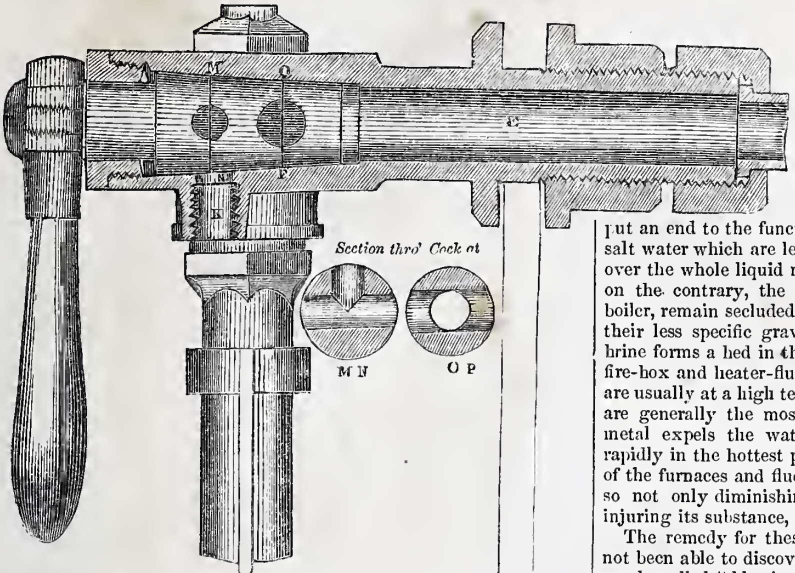
By J. Scott Russell, M.A., F.R.S.E., F.R.S.S.A., Civil Engineer.

It was very early in the history of steam navigation that the inconvenience of raising steam from salt water was experienced. When the Comet descended below Port-Glasgow in 1812, the boiler was found to boil over, or prime, as it is technically called by engineers, when part of the water is forced up so violently, along with the steam, as to pass over into the cylinder of the engine—a circumstance always detrimental, and sometimes destructive to the engines. This arises from the thickening of




the water, its density being increased by the retention of the solid substances which compose sea-water, and which remain and accumulate in the boiler, while the fresh portion of the water is passing off in the shape of steam.

This process of accumulation of solid matter in the marine boiler is by no means slow. The whole of the water which a marine boiler usually contains is evaporated in three or four hours, leaving the solid substances in the cubic content of boiler behind it, and being replaced by salt water, with an equal quantity of depository matter, accumulating as rapidly as before; and since it is known that the solid matter amounts to as much as $\frac{1}{33}$ of the whole mass of water, it would follow, if the process of ebullition could continue so long as 150 hours, there would be deposited in the boiler a quantity of solid matter equal to the number of tons of water in the whole content of the boiler.

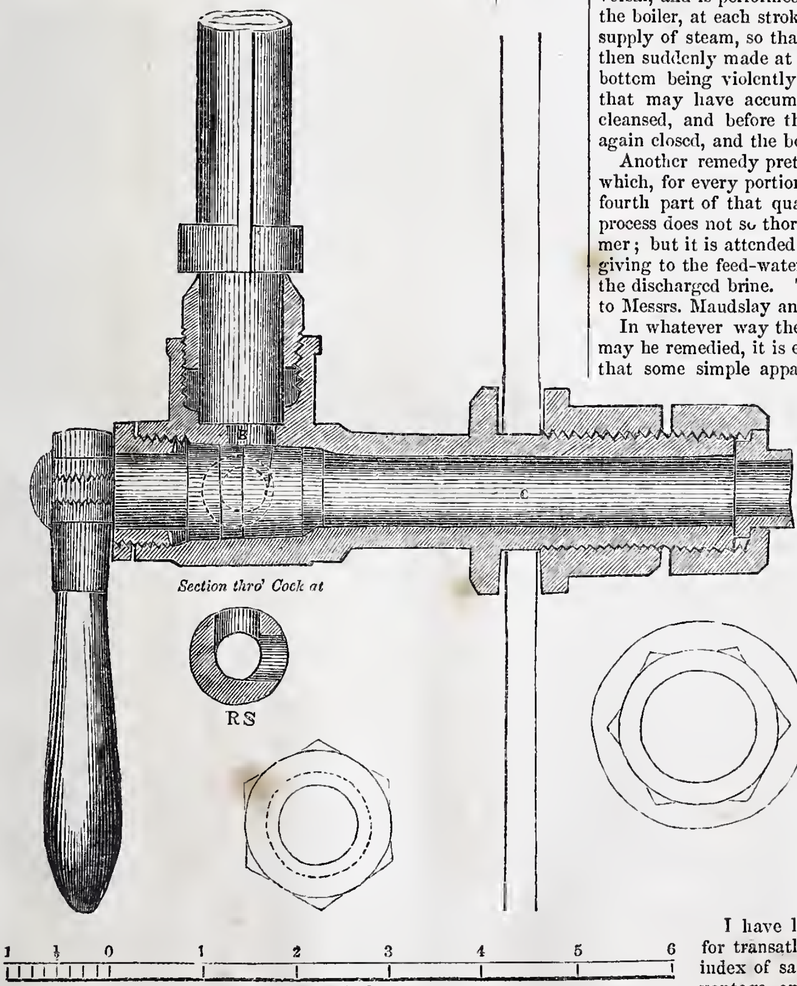



Long, however, before this degree of solidification can take place, evils of a different description intervene to impair and put an end to the functions of the boiler. The solid constituents of salt water which are left behind, do not diffuse themselves uniformly over the whole liquid mass, so as to constitute a homogeneous brine; on the contrary, the new supplies of sea-water, as they enter the boiler, remain secluded from the former more saturated brine, rise by their less specific gravity into an upper stratum, while the denser brine forms a bed in the lower part of the boiler, and surrounds the fire-box and heater-flues occupying the water-spaces and legs, which are usually at a high temperature, and which, in double-tiered boilers, are generally the most intensely heated. The intense heat of the metal expels the water from the brine in contact with it most rapidly in the hottest places, and salt is deposited on the hottest parts of the furnaces and flues, extending rapidly to those less heated, and so not only diminishing the evaporative power of the boiler, but injuring its substance, and endangering its existence.

The remedy for these evils was very early invented. But I have not been able to discover the inventor of the cleansing process commonly called "blowing down," or "blowing off." It is almost universal, and is performed in the following way:—There is forced into the boiler, at each stroke, rather more water than is required for the supply of steam, so that the boiler becomes too full. Openings are then suddenly made at the bottom of the boiler, and the brine at the bottom being violently ejected, carries with it any solid substances that may have accumulated near the bottom; the boiler is thus cleansed, and before the water has got too low, the openings are again closed, and the boiler continues to be fed as formerly.

Another remedy pretty generally adopted, is the brine-pump, by which, for every portion of water supplied to the boiler, about one-fourth part of that quantity of brine is withdrawn from it. This process does not so thoroughly carry off all the impurities as the former; but it is attended with a saving of fuel, by a contrivance for giving to the feed-water entering the boiler a portion of the heat of the discharged brine. The recent introduction of this process is due to Messrs. Maudslay and Field of London.

In whatever way the saturation of the water with solid matter may be remedied, it is essential to the accomplishment of this object, that some simple apparatus should be contrived for the purpose of showing when the cleansing process is required, and whether it is successfully applied. If this be not obtained, the usual consequences of acting on wrong data are sure to follow.




Scale of Inches.

A contrivance was patented which was thought promising, but was found liable to be mechanically out of order when most wanted;—a ball of greater specific gravity than salt water was connected with an external index, by which there was indicated on the outside the fact of the brine becoming sufficiently saturated to float this ball.

Another was to place in the glass gauge of the boiler a glass hydrometer bead, which would float when the brine became saturated to a given point, and fall to the bottom in the ordinary state of the boiler. But this fails entirely of accuracy, although very elegant; for the brine of which we wish to indicate the density is in the lower stratum, not the upper one, where the usual glass gauge is placed, and irretrievable mischief might be done before the indication would show any change.

I have lately employed, in some large ships destined for transatlantic voyages, a species of brine-gauge, or index of saturation, which is found to possess every advantage, and which I therefore desire to communicate

to the public through this society. The accompanying drawings are such as may enable any engineer to construct them for himself. The details of the arrangements of the apparatus were made under the direction of Mr. James Laurie, formerly one of my assistants; and he also has obliged me by writing out the annexed description of the operation of using the index.

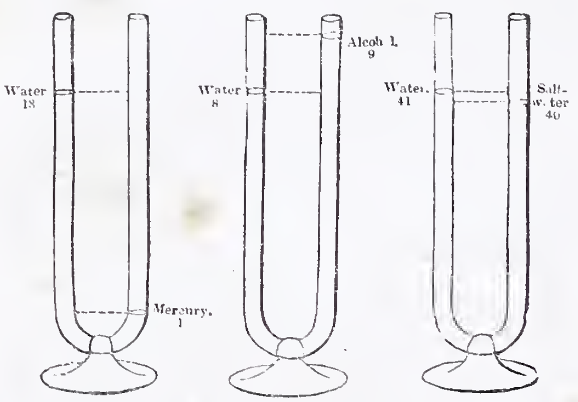
The principle I have used is the well-known law, "that the heights of equiponderant columns of liquids vary inversely as the densities of those liquids."

If I take open glass tubes, bent in the form of the letter U, as in the diagram, (fig. 1,) and pour one fluid into one of the sides, and another fluid into the opposite side (taking care to use the heavier liquid *before* the other), the one being mercury, and the other water, they will stand at the height of 1 inch and 13 inches respectively. If I use alcohol and water, (fig. 2,) they will stand at the height of 10 inches and 8 inches respectively, the height of the one fluid being always greater than that of the other, in the proportion in which its weight, density, or specific gravity is less.

In like manner, fresh water and salt water (fig. 3) will stand at heights of 40 and 41 inches, showing a difference of 1 inch.

The use which I make of this principle is as follows:—I reckon the best scale of saltness of a boiler to be that which takes the common sea-water as a standard. Sea-water contains $\frac{1}{30}$ of saline

*Fig.* 1. *Fig.* 2. *Fig.* 3.




matter. When the water has been evaporated, so as to leave only half the quantity of distilled water to the same quantity of saline matter, I call that two degrees of salt, or brine of the strength of two, and such brine would show, in fig. 3, the columns 40 and 42, or double the saltness of salt water, indicated by a difference of 2 inches. A further saturation would be indicated by a difference of 3, 4, 5, and 6 inches between the columns, and so indicate 3, 4, 5, 6, and any further degrees of saltness—a range which may be made to any degree of minuteness by the subdivision of the scale of inches. This scale is that which appears to me most simply applicable here —and it is that which I adopt for marine boilers.

The mechanical apparatus which I have employed to give this indication is perfectly simple, and has the advantage of being such as the engineer already perfectly understands. To the marine boiler I apply two water-gauges of glass, instead of one as at present used; they both serve the purpose of the present glass gauges, and the pair would be valuable for this, if for no other reason, that there would always be a duplicate when one is broken, an accident not unfrequent. To these gauges I simply attach smaller copper pipes, so that one of them may be placed in communication only with the salt brine in the lower part of the boiler, and the other with the feed-water which is entering the boiler; the one then holds a column of brine, and the other of pure sea-water, and each inch of difference shows the degree of saturation.

Without the use of any attached scale, the engineer, by a little practice, comes to know, in his particular vessel, what difference in inches can be admitted without danger, and at what difference of height it is imperative to blow off. But it is convenient to have an attached scale.

It may be satisfactory to state, that the practical range of scale in an ordinary boiler in the ordinary working, is 6 to 10 inches—a difference sufficiently great to be easily observed.

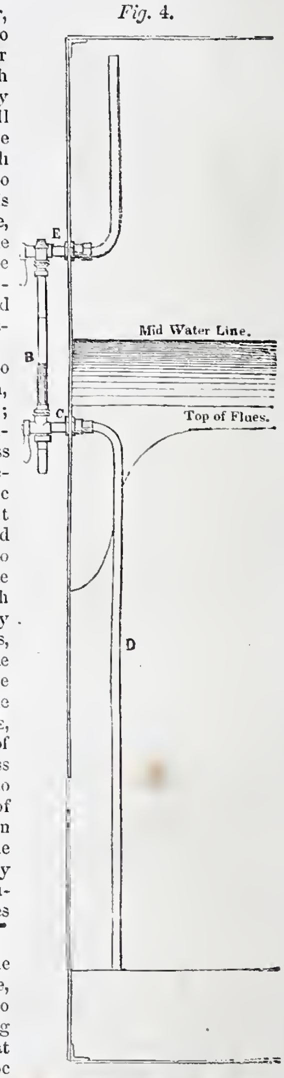
The rule of working them is nearly this:—Continue the operation of blowing off, until, if possible, the difference of the columns is less than an inch; it will be unnecessary to blow off again until the difference is at least 6 inches.

As a practical rule, I find that it is necessary to blow off when the brine at the bottom has about three degrees of saltness. But this will vary exceedingly, according as the construction of the boilers is more or less judicious. When the heat is greatest in the lowest portion of the boiler, and the flues return above, they will be most liable to salt, and require the most frequent cleansing.

The following is Mr. Laurie's description of the instrument. The drawings give the details of the apparatus.—J. S. R.

The fact that the specific gravity of salt water is greater than that of fresh, and that it increases with the degree of saturation, is what the operation of this instrument depends on; by its means two columns of water, the one feed and the other brine, are poised against each other, so as that any difference of weight betwixt these columns immediately becomes apparent, by the lighter of the two requiring an accession in quantity to resist the upward pressure to which both columns are subjected. This is accomplished by having two common glass gauge-tubes close together, each of which is connected with a separate tube; that inside the boiler descends to the level of the water, the specific gravity of which is to be measured, and having either or both of these tubes so connected with the feed-pipe of the boiler, that, by opening a cock, one of the pipes will be filled with feed-water, while the other remains filled with brine, which cock being shut, the tubes remain so filled; but inasmuch as feed-water is of less specific gravity than brine, it will be forced up and stand in the glass tube at a higher level than the brine, which difference of levels increases with the saturation—and hence the index to judge of the saltness.

*Fig.* 4.




In the engraving, A B are the two glass gauge-tubes (only one of which, B, is seen in the annexed diagram); C, one of the tubes forming the connection betwixt one of these glass gauge-tubes and its tube, D, that descends inside of the boiler; E, the tube forming the connection betwixt the upper ends of these tubes and the inside of the boiler; F, G, two cocks, so made, as shown in the drawing, that by their means each of the tubes inside of the boiler may be shut off from the glass tubes, and also may be connected with the tube, H, leading from the feed-pipe of the boiler; I, a cock affording the means of shutting off the tube, E, from the glass tubes, and also of connecting either of these glass tubes with the tube, K, leading to the bilge of the vessel; each of these cocks has a handle, and when the instrument is indicating, the three handles hang perpendicularly downwards. To bring the instrument into operation, the three handles must first be put in the position which has the effect of allowing the brine to flow right up the glass tube, A, and out through the tube, K, into the bilge of the vessel; this having been done for so long a time, as that A and its tube inside the boiler be thoroughly cleansed and filled with brine, the handles are then to be put in the position, which, in like manner, cleanses and fills B and its tube inside of the boiler with brine; finally, bring the handle of the top-cock into its original position, and put either of the lower handles horizontal, which, forming a connection of the feed-pipe with one of the tubes inside of the boiler, fills that tube with feed-water; thus there are in the two tubes inside of the boiler two columns of water of different specific gravities, the one being brine, the specific gravity of which is to be measured, and the other feed-water, the specific gravity of which is pretty nearly constant, so long as the temperature of condensation is the same, and does not vary much, let

# CIRCULAR MOTION CONVERTED INTO CIRCULAR MOTION.

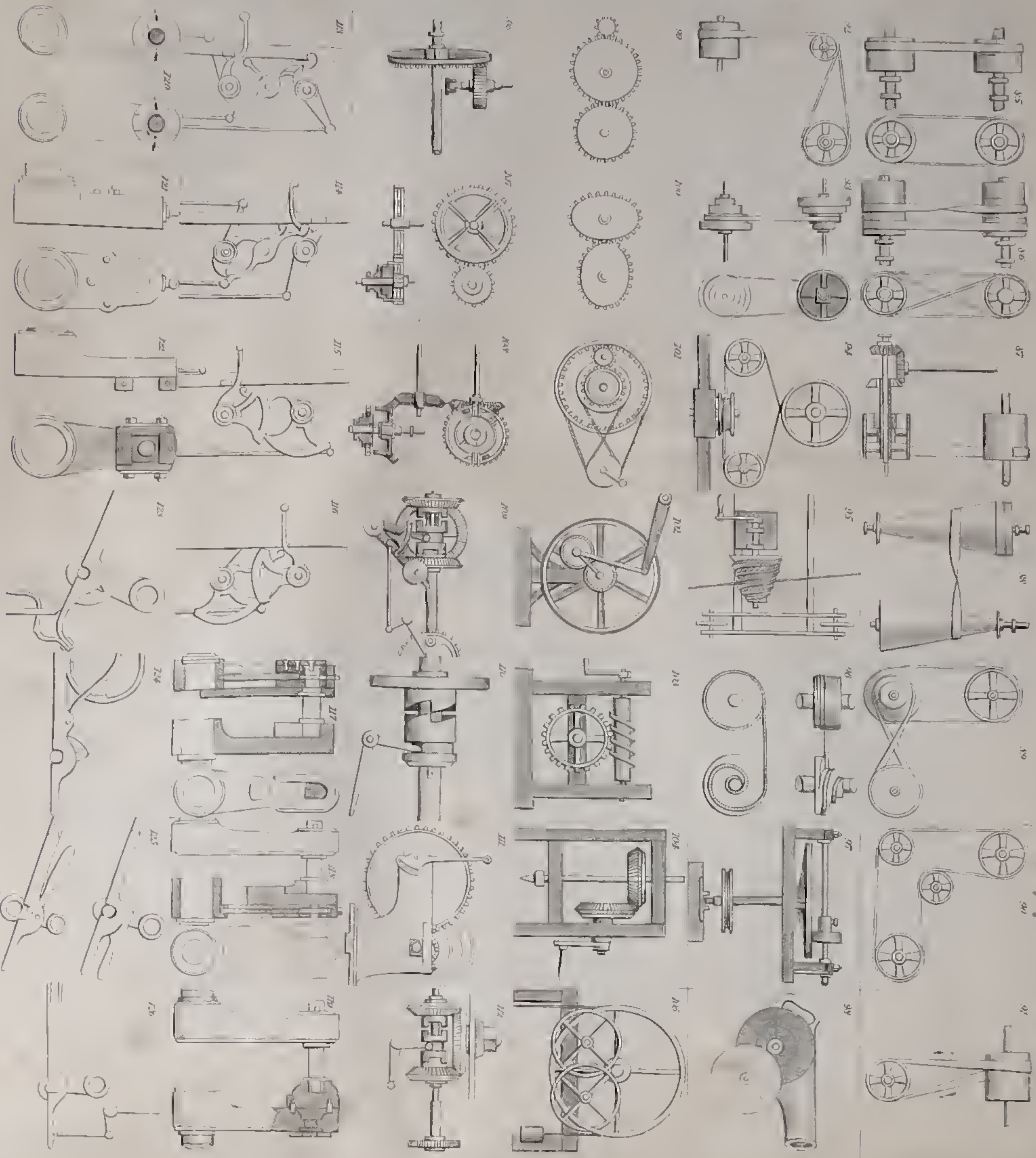


TABLE OF MECHANICAL MOVEMENTS.

Illustrated By publisher

the temperature of condensation be what it may; but, inasmuch as these columns of water are of different specific gravities, the pressure on the bottoms of them will force the lighter up the glass tube, until such a quantity of brine has followed it as makes it of equal weight with the other; and hence, in the two glass tubes, the water stands at different heights, the magnitude of which difference becomes known by means of the scale fixed betwixt the glass tubes, and therefore also the degree of saturation of the brine.

The use of this instrument, which might be called a Salinometer, is not confined to this one object, for it answers thoroughly all the purposes of the common glass gauge, the position of the surface of water in the boiler being midway betwixt the surfaces of water in the tubes.

When either or both of the glass tubes is broken, put the handles in the position !!, and nothing can escape from the boiler.—T. W. L.

## ANALYTICAL TABLE OF MECHANICAL MOVEMENTS.

### PLATE III.

*Description.*

85. Represents the contrivance called the single fast and loose pulley, used for connecting or disconnecting machines to or from the moving power. The drum at the lower part of the figure being made to revolve, communicates motion by the belt to the fast pulley on the shaft at the top of the figure, when the belt is on the fast pulley as represented. By shifting the belt to the right it is thrown upon the loose pulley, which turns round without moving the shaft. The figure to the right is an end view.

86. Is a similar contrivance for engaging and disengaging, and also for reversing the motion of the shaft at the top of the figure, by means of the open and cross belts. There are three pulleys on the upper shaft, the centre one being fixed and the other two loose. The cross belt is represented on the fixed pulley. When the lower drum is made to revolve, rotatory motion is communicated to the fixed pulley, thereby driving the shaft in the reverse direction from the lower drum. The open belt is upon one of the loose pulleys. Suppose the cross belt be now shifted on to the loose pulley to the left, both belts being on loose pulleys, the upper shaft will remain at rest. If now the open belt be shifted on to the fixed pulley, the revolution of the drum below will set the upper shaft in motion in the same direction as the drum, and contrary to the motion communicated by the cross belts. This is generally used in certain descriptions of planing machinery.

87. Is a modification of the foregoing, combined with bevel wheel and pinions. Three pulleys are shown in section on the right hand end of the lower shaft. The pulley to the right is fixed upon the same shaft on which the pinion to the left is fixed, and when set in motion by the belt passing over the drum at the top, will communicate motion to the perpendicular shaft by means of the pinion to the left acting on the bevel wheel. The central of the three pulleys is loose, so that when the belt is thrown upon it, the lower machine remains at rest. The pulley to the left of the other two is fixed on a hollow shaft, to the end of which the pinion to the right of the one just mentioned is also fixed, and when motion is communicated to the hollow shaft, the bevel wheel and perpendicular shaft receive a motion the reverse of the former. This is also used in planing machines.

88. Represents a contrivance called the inverted conical drums. According to the position of the belt upon the drums the speed of the driven drum will be greater or less than that of the driver. This movement is generally used by rope spinners.

89. Is an end view of 88, with the addition of a pulley from which the cones receive motion.

90. Is a simple arrangement by which, with the help of guide pulleys the belt connecting two drums may be placed in any convenient position.

91. Is a method of communicating motion to a shaft at right angles to that from which the power is derived.

92. Is the same as 91, with the addition of a guide pulley to alter the direction of the belt.

93. Is a front and end view of a contrivance for effecting the same purpose as the conical drums.

94. Is an arrangement for transferring circular motion by means of an endless band. The speed is necessarily varied according to the diameters of the respective pulleys.

95. Is a plan in which the application of a spiral fusee varies the traverse of a carriage according to the diameters on which the band acts.

96. Is a contrivance by which the uniform motion of the shaft to the left will communicate a variable motion to the shaft to the right, by the belt set upon the spiral pulley. It is somewhat similar to the fusee of a watch.

97. Represents what are called buff wheels. The flat plate on the top of the upright shaft being turned by means of the sheeve on its bottom communicates motion to the pulley on the horizontal shaft. The surfaces of the plate and the pulley are covered with buff leather, thereby producing sufficient friction to communicate motion from the one to the other, which motion may be reversed if the pulley be shifted to the left hand, or varied in speed as it is nearer or farther from the centre of the plate.

98. Is a small portable fanner blast, applicable for domestic use. Its principle and construction are the same as the large fanner blast used for furnaces. By turning the large buff wheel with the hand, rapid motion is communicated to the small one fixed upon the end of a spindle on which the fanner is fixed in the inside. By the rapid motion of the fanner, the air is driven out at the nozzle.

99. Circular motion transferred by spur wheels.

100. One of the oval wheels being driven at an uniform speed, will produce a regularly varying speed in the other.

101. Suppose the small warve or pulley on the right to be the driver, the larger wheel with an internal rack, and the concentric wheel within, will be driven in opposite directions by the bands as represented; and at the same time impart motion to the intermediate pinion on the left, both round its own centre, and also round the common centre of the circular rack and concentric wheel.

102. This arrangement is commonly called the sun and planet wheels, and was first extensively applied, if not invented, by the celebrated James Watt. Two spur wheels are held in gear by a strap or connecting rod from their respective centres; the one being fast on a shaft, and the other fast to the connecting rod which proceeds from the beam on the left, the vibration of which carries round the fly-wheel at the same time that the fixed spur wheel on the connecting rod is revolved round the spur wheel into which it gears.

103. The circular motion of a screw transferred to a bevel wheel, commonly called a worm wheel, is one of the most efficient modes of reducing speed.

104. Where circular motion is required to be transferred in a direction not parallel to the driver, bevel wheels are generally used as in this example.

105. Represents Attwood's contrivance for reducing friction. The axis of the large wheel rests upon the periphery of the two smaller, thereby making the friction of the large wheel rolling, and transferring the rubbing friction to the axis of the smaller wheels where the motion is so much diminished, as to make the friction very little.

106. Is a face wheel and pinion, used where it is necessary to communicate motion from one shaft to another at right angles. Commonly used in grain mills.

107. Represents a method of communicating motion by means of friction. The lower figure represents a section of the upper wheel and pinion. The larger wheel is fixed on its shaft, and the pinion loose upon its shaft, upon which a catch with a conical end is fixed by means of a feather. Upon the side of the pinion is an inverted conical seat, corresponding to the end of the catch. When the catch is forced into its seat, it carries the pinion round by friction. In the event of the wheel being obstructed, the conical catch slips round in its seat, thereby avoiding breakage. It is generally used where the power to be overcome is of a variable nature.

108. Is a contrivance for answering the same purpose as the last, by means of a friction strap, embracing the pulley shown in section on the lower end of the shaft at the bottom of the figure. When the lower pulley is pushed up to the back of the wheel, the flanges by which the two halves of the strap are bolted together, come into contact with the projecting pieces on the back

of the wheel, and thereby carry it round, communicating motion to the wheel on the left. In the event of obstruction, the shaft and pulley slip round within the strap. The upper figure is another view of the same.

109. Is a contrivance by which a machine is made to reverse its own motion. Motion is communicated to the machine on the right through the bevelled wheels to the left of the figure. The bevelled wheel in the centre to the left turns the wheels at its sides to contrary directions, but as those wheels are loose in the shaft, no motion is communicated to the machine, except when the catch box is connected to the one or other of the wheels. The present position of the catch makes the wheel on the right of the centre wheel the driver one. If we suppose then the spur-wheel, a part of which is seen to the right of the figure, to be turned round, so as to make the stud near its periphery move the arm of the bell-crank lever, so that the lever with the ball on it is pushed past the perpendicular, the ball will then fall down to the left, moving the catch box into connexion with the wheel to the left, thereby reversing the motion of the machine, till the stud in the spur wheel coming round in the contrary direction, brings the ball back to its present position, and thereby again reverses the motion.

110. Is a slip catch by which the moving power can only communicate motion to a shaft in one direction. This is often introduced to obviate the evil of a backward stroke of a steam-engine.

111. Is a method used for engaging and disengaging what is commonly called the back speed of a turning lathe. The lever to the left has an eccentric slot in its lower end. A pin fixed on the buss of the wheel moves in the eccentric slot. When the upper end of the lever is drawn towards the left, the pin carrying the buss is pushed to the right, thereby connecting the wheel with the pinion.

112. In the position shown in the figure, if motion be communicated from the spur wheel to the right to the bevel-wheel next it, the horizontal bevel wheel is put in motion, and communicates motion to the bevel wheel to the left. If by the action of the bell-crank at the lower part of the figure, the catch is pushed to the left, the bevel wheel to the right is allowed to run loose on its shaft, which shaft is at the same time connected to the shaft on which the bevel wheel to the left is fixed, and communicates motion, the reverse of what took place in the other case.

113, 114, Represent the diagonal catch commonly used in the hand gear for blowing and pumping engines. In 113, the lower steam valve, and the upper eduction valve of the steam nozzles are open, while the upper steam valve, and lower eduction valve are shut, consequently the air-pump rod will be ascending. In its ascent the lower handle will be struck by the projecting tappet, and being raised will become engaged by the catch, and shut the upper eduction and lower steam valves, at the same time the upper handle being disengaged from the catch, the back weight will pull the handle up, and open the upper steam and the lower eduction valves, when the piston will consequently descend. Fig. 114 represents the position of the catch and handles, when the piston is at the top of the cylinder. In going down, the tappet of the air-pump rod strikes the upper handle, and throws the catch and handles into the position of 113.

115, 116, Represent the same as the preceding two, with the exception of the diagonal catch, which is here superseded by two quadrants.

117, 118, 119, 120, 121, 122, are various modes of disengaging paddle wheels from the engine; 117 also affords means of shortening the stroke of the engine. In 117, the crank pin is fixed into a sliding block, connected with the crank to the left, which block may be moved by the screws attached thereto, so as to bring the crank pin nearer to the centre of the shaft, thereby shortening the stroke of the piston. The figure to the right is a face view of the crank next it. If the crank pin is screwed down, as represented in this view, the other crank will move round, without communicating motion to the paddle.

118. Differs from 117, only in so far, that instead of the crank pin being moveable, by the screw, the slot in which the pin catches is moveable, and when screwed down below the range of the pin, the one crank moves round without moving the other.

119, and 120. The pin which is fixed in the crank to the left, will communicate motion to the crank to the right, when the pin is fixed in the circular slot, as shown in the right hand figure of 120. But when the slot (which is moveable) is placed in the position of the left hand figure of 120, the pin moves through the slot without turning the paddle crank.

121. Is an edge and front view of another construction of crank. The upper part may be altogether disengaged by unscrewing the bolts which hold the two parts together, thereby disconnecting the paddle wheel.

122. Is for a similar purpose: it differs from the former, in so far that the two side pieces, represented bolted together, may be screwed off, the brass busses taken out, and the crank pin will move round without turning the paddle crank.

123, 124, 125, and 126. Are different methods of throwing engines out of gear. These represent the end of the eccentric rod next the valve, and the means by which the rod is disconnected from the lever on the end of the valve shaft. The gab is represented taking hold of the pin, which, being made to traverse by the motion of the eccentric, communicates a reciprocating motion to the valve. The lever and spring below the rod in 123, and above in 124, show the method by which the rod is disconnected from the pin, and thereby leaving the valve at rest. The same result is effected in 125, by turning round the small lever with the eccentric on its end. The same result is also effected in 126, by means of the bell-crank shown, which lifting up the rod keeps the pin free of the gab.

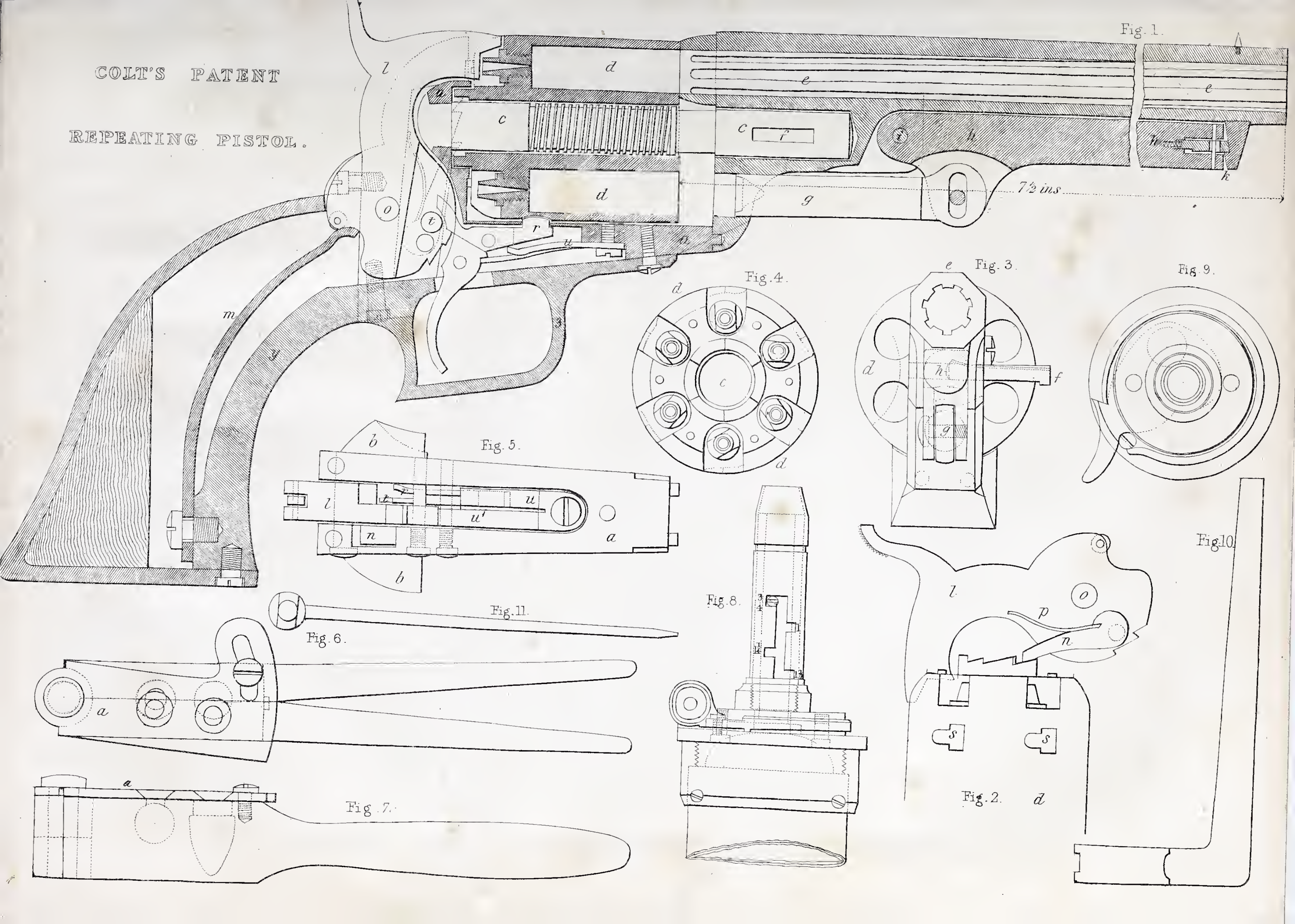
We have now furnished our readers with 126 representations of different kinds of mechanical movements. In these will be found many of the most ingenious and useful contrivances which are used in the operations of machinery, or the processes of manufacture. By carefully studying and committing them to memory, the mechanic, and those who practise their inventive powers, will have a store of knowledge regarding the operations of machinery, which will be eminently useful in enabling him to effect any kind of movement required. There are some figures which, from their importance, or the principles on which they depend, require a separate and more extended description: these will be supplied throughout our future numbers. This month we stop these representations for a short time; perhaps two or three months, during which time we shall be collecting materials for another series. As in other things, we solicit the assistance of our friends in this. By sending us drawings and descriptions of any new movement, or any not generally known, they will enable us to make the series more complete, and therefore more valuable to the mechanic.

## COLT'S PATENT REPEATING PISTOLS.

(*Illustrated by Plate.*)

It is a vain prejudice to suppose that this country may not be surpassed by other nations, even in mechanical ingenuity. In the Great Exhibition, France asserted an easy supremacy in many branches of manufacture; the number of prizes which she gained in proportion to the list of competitors was surprising. Prussia has outstripped us in her needle gun; the Americans beat us in locks; and we fear we must also acknowledge that they have taken a decided lead in the improvement of fire-arms. We have previously alluded to Deane's revolver pistol, which was shown at the Exhibition, and has been highly approved; but Colonel Colt's, which we are about to describe, was prior in point of invention, and seems to be unrivalled in the ingenuity of its mechanism. It is really a beautiful contrivance, and most of the revolving fire-arms exhibited in this country are simple imitations of it. The common objection to all such arms is, that they are easily deranged, and difficult to keep in order. To test this point with reference to Colonel Colt's pistols, the Board of Ordnance, United States, had one of his holster pistols fired twelve hundred times, and one of his belt pistols fifteen hundred times, cleaning but once a day, when the arms were found to be in perfect working order; and the Board determined, as our readers will also admit, that no farther trial was necessary. The holster pistol was found to penetrate through seven inches of board, and the belt pistol through six inches, whilst the deepest penetration of the com-

# COLT'S PATENT REPEATING PISTOL.



mon dragoon pistol was only through five inches. This trial was deemed so satisfactory, that the Secretary of War at once assumed the responsibility of contracting with Colonel Colt for 4000 pistols, without waiting for the official sanction of Congress. No such readiness to patronise and adopt even the most decided improvements is found in this country. With us, when anything appears to be valuable, no inconsiderable difficulty is found in getting a committee or commissioners appointed to investigate its merits; and then it must pass through the ordeal of a blue-book, and parliamentary discussions, perhaps frequently adjourned, before it can ultimately force its way into the light of Government patronage. Hence the backwardness of this country in many modern departments of invention—especially in that of fire-arms; but it is to be hoped that the facilities afforded to discoverers by the new patent law, will enable us speedily to recover our lost gound.

We present our readers with a plate, *full size*, of Colonel Colt's patent repeating pistol. Fig. 1 is a side elevation in section, the barrel being broken off; fig. 2 is an elevation of the hammer, and chamher detached; fig. 3 is an end view of the mouth of the barrel, which, it will be seen, is rifled, and also of the mouths of the chamber for containing the charges; fig. 4 is a view of the other end of the chamher, showing the nipples for the percussion-caps; and fig. 5 is an inverted plan of the trigger, the spring which actuates it, and the hammer, but without the brass finger-guard, *y z*, shown in fig. 1. Figs. 6 aud 7 are a plan and elevation of the bullet-mould; fig. 8 is an elevation, and fig. 9 a plan of the upper end of the powder-flask; and figs. 10 and 11 show the screw-driver, one end of which fits the nipples, and the other the ordinary screw-head. With the aid of these figures, we shall be able to render the mechanism perfectly intelligible to the reader; and, first, we shall describe the manner in which the various parts are secured together.

The basis of the stock is the piece of metal, *a a*, at the back of which is a boss, *b b*, shown in fig. 5, and shown also dotted in fig. 1, which is cored out, to receive the hammer, trigger, &c., and serves to cover the nipples. This boss is cut away on one side, as shown in fig. 5, to give room to put the percussion-caps on the nipples, and in it is fixed a cylindrical pin, *c c*, which forms the centre or axis of the system, and on which the chamber, *d d*, revolves; a shallow thread being cut in the pin at the part embraced by the chamher, to hold the oil which is essential to enable the chamber to revolve freely. This pin likewise supports the barrel, which is fixed to it hy means of the key, *f*; and by driving up this key, the harrel is forced into contact with the chamber, *d*, while the chamher, by the same movement, is brought into close contact with the boss, *a*. A small screw is fixed in the barrel, the head of which enters a groove in the key, to prevent the latter from being disconnected and lost; and on the front of the piece, *a a*, are two small pins, which serve to steady the barrel, the latter having holes bored to receive them in the projection at the eud of it. The ramrod, *g*, is guided into the mouths of the chamber by sliding through the projection forged on the barrel, and is impelled by the lever, *h*, working on the pin, *i*, as a fulcrum. This lever, when not in use, is held in position by means of the spring catch, *k*, and is fixed in its place by the mere act of grasping it with the barrel; by pressing down the projecting tongue, which extends transversely for this purpose beyond the diameter of the lever, the latter can be instantaneously disengaged. The hammer, *l*, moves on the pin, *o*, as a fulcrum, and is actuated by the spring, *m*, which bears on a friction roller in the heel of the hammer.

It will be seen that, by this arrangement, whenever the harrel and chamber have become foul from use, they can easily be taken to pieces and cleaned. For this purpose, the key, *f*, has only to be driven hack, and both the barrel and chamber can then be slipped off the pin, *c*, cleaned, and put together again in a few minutes.

Having thus explained the structure, let us now see how the movements of the chamber and hammer are provided for. It will be observed that the chamber is constructed to carry six charges of powder and ball, and must therefore be moved one-sixth of a revolution each time: it must also be held rigidly in a line with the barrel at the moment of firing, and it must be capable of making a complete revolution, in order to load it. The manner in which the chamber is made to rotate is shown in fig. 2. It will he observed that the back end of it is cut into a circular ratchet of six teeth, and this is moved round by the lever, *n*, which is attached by a pin to the hammer, and held against the ratchet hy means of the spring, *p*, so that the chamber can turn only in one direction. When the hammer is raised in the act of cocking, the chamber is moved by this arrangement one-sixth of a revolution; and when the hammer is falling, the chamber is held by the lever, *r*, (figs. 5 and 6,) the end of which has a tooth in it, taking into one of the notches, *s*, *s*, &c., of which there is one over each nipple. The other end of the lever, *r*, is moved by the pin, *t*, fixed in the hammer, and so adjusted that, as the hammer rises, the lever is out of the notch, *s*, and the chamber released, before the ratchet is made to revolve by the lever, *n*. When the hammer is at half-cock, the lever is clear of the notch, and the chamber can be freely revolved and loaded; but before the hammer is brought to full-cock, the pin, *t*, passes the end of the lever, *r*, and the latter, being released, is forced by the spring, *u*, into the notch, *s*, to hold the chamber in the right position at the moment of firing. It is obvious that, if some provision were not made for the purpose, the pin, *t*, having passed the end of the lever, *r*, in going up, could not repass it in coming down, and therefore the hammer, in falling, would not strike the nipple. This difficulty is overcome hy splitting the end of the lever, *r*, in two pieces, (as shown in fig. 5,) on the inner of which only the pin, *t*, acts; and the point of the pin is bevelled, so that in its deseent it causes the two pieces of the lever, *r*, to collapse, and passes them without obstruction, their elasticity extending them agaiu after it has passed.

The spring, *u*, is also divided into two parts; one, *u*, acting on the lever, *r*, and the other, *u'*, on the trigger, to keep it in contact with the hammer.

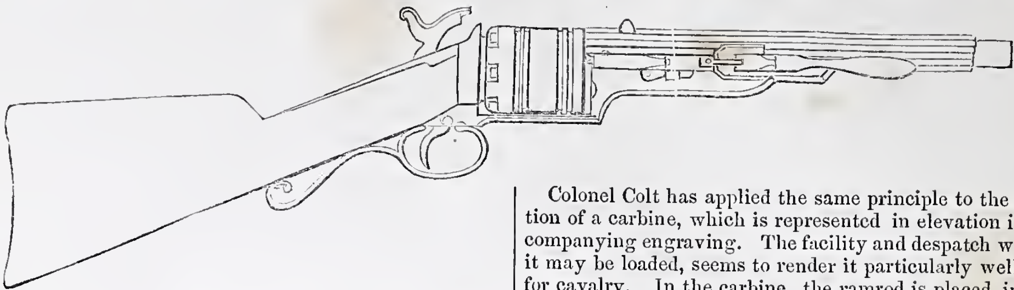
We shall now describe the method of using this arm. In loading it, the hammer is half-cocked, which, as we have seen, sets the chamber at liberty, and the powder is poured into each of the six receptacles in succession, the balls being put on the powder without any wadding, and rammed down by the lever All this is the work of a minute, for the chamber, not being rifled, although the barrel is, there is no difficulty in ramming the balls home; whilst the damage to the sharp edges of the grooves, which always takes place in ordinary rifles, from the force with which the ramrod must be used, is wholly avoided. The hammer is readily raised to full-cock by the thumb, and in this position forms the sight hy which to take aim.

Though thus easily loaded and fired, the accidental discharge of the pistol, whilst heing carried in the poeket or belt, is effectually provided against by an ingenious arrangement. Between each nipple, as shown in fig. 4, is a small pin, and the point of the hammer has a corresponding notch, so that, if the hammer be lowered on to the pin from half-cock, the chamber is prevented from revolving, while the hammer is not in contact with the percussion-cap. In this position the cap cannot explode, even if the hammer should be struck violently by accident.

Another invaluable quality possessed by this pistol, but never attained by the ordinary musket, is the power of resisting the effect of moisture, and even of absolute immersion in water. The receptacle for the powder is hermetically sealed by the power required to thrust the ball home, and, with the cap on the nipple, it has been found that the pistol may be immersed in water for several hours without damping the powder.

The only other fittings necessary for the pistol-case are the bullet-mould, powder-flask, and screw-driver, already referred to in the plate. The bullet-mould (figs. 6 and 7) is formed of brass, and is provided with two moulds—one for the conical ball, and another for the ordinary spherical one. The plate, *a*, which forms the cover of the mould, as shown in the elevation, fig. 7, is made of steel, and the hole in this plate through which the lead is poured has a knife-edge, so that, after the ball is cast, the runner on the ball is neatly cut off by simply moving the cover, as shown in fig. 6. The upper end

of the powder-flask is shown in figs. 8 and 9; the mouthpiece of the flask is fitted with a bayonet-joint, by which the supply of powder can be measured off by shifting the mouthpiece to $\frac{3}{4}$ or $\frac{5}{8}$ of a drachm, &c., according to the several sizes of the arm. Figs. 10 and 11 represent, as already stated, the screw-driver, which completes the requisite fittings.



Colonel Colt has applied the same principle to the construction of a carbine, which is represented in elevation in the accompanying engraving. The facility and despatch with which it may be loaded, seems to render it particularly well adapted for cavalry. In the carbine, the ramrod is placed in the side of the barrel, instead of below it, and this is the only difference of arrangement from that adopted in the pistol.

## PHOTOGRAPHY, OR PHOTOGENIC DRAWING, THE CALOTYPE, DAGUERREOTYPE, &c.

### CHAPTER II.

#### PROCESSES FOR COPYING ENGRAVINGS, BOTANICAL SPECIMENS, &c., WITHOUT THE CAMERA OBSCURA.

Having given, in our first chapter, a brief account of the early history of photography, and other introductory details, we shall now proceed to explain the different processes by which it is most successfully practised. In doing so, we shall describe, in the first place, the processes in which paper is used, as being the more simple; and we shall devote the present chapter to the more elementary processes in which the use of the camera obscura is dispensed with.

This department of our subject cannot be better introduced than in the words of Mr. Talbot's first account of his earliest photographic experiments, published, as already stated, in 1839. In that account, Mr. Talbot thus described his method:—"In order to make what may be called ordinary photogenic paper, I select, in the first place, paper of a good firm quality, and smooth surface. I do not know that any answers better than superfine writing paper. I dip it into a weak solution of common salt, and wipe it dry, by which the salt is uniformly distributed throughout its substance. I then spread a solution of nitrate of silver on one surface only, and dry it at the fire. The solution should not be saturated, but six or eight times diluted with water. When dry, the paper is fit for use. . . . . This paper, if properly made, is very useful for all photogenic purposes. For example, nothing can be more perfect than the images it gives of leaves and flowers, especially with a summer sun—the light, passing through the leaves, delineates every ramification of their nerves."

This process for preparing the paper was not always successful, and Mr. Talbot selected, from different sheets thus prepared, those which appeared to be the most sensitive, for placing in the camera obscura. His mode of fixing the picture at that time was, by simply washing it with a solution of common salt. "It may appear strange to many," says Mr. Hunt, "that the same material which is used to give sensitiveness to the paper should be applied to destroy it. This may be easily explained: in the first instance, it assists in the formation of the chloride of silver; in the other, it dissolves out a large portion of that salt from the paper, the chloride being soluble in a strong solution of muriate of soda (common salt). When common salt is used, the solution of it should be tolerably strong. The picture being first washed in water, is to be placed in the brine, and allowed to remain in it for some little time; then, being taken out, is to be well washed in water, and slowly dried. If the brine is used in a saturated state, the white parts of the photograph are changed to a pale blue—a tint which is not, in some cases, at all unpleasant. I have in my possession some pictures which have been prepared more than eight years, which were then fixed with a strong brine, and subsequently washed with warm water. They have become slightly blue in the white portions, but otherwise they are very permanent; and they have lost but little of their original character.

In the copying of engravings, and several small objects, the beginner may practise this rude and simple process without the aid of a camera. For this purpose, the only chemical agents required are nitrate of silver and common salt. The nitrate of silver should always be procured, if possible, in the crystallized state, and not in the form of cylindrical sticks, into which it is usually moulded when fused, and sold by the apothecaries under the name of caustic. The crystallized salt may easily be made by dissolving a piece of pure silver in aquafortis, and allowing the solution slowly to evaporate to dryness. When the paper has been first dipped into a weak solution of common salt, then dried, and afterwards washed over with the nitrate, the chloride of silver is formed by the union of the chlorine of the salt with the metallic base of the nitrate; and this chloride of silver affords the sensitive surface, which darkens on exposure to light. On a sheet of paper thus prepared, let a leaf, a feather, a wing of a butterfly, an engraving on paper, or any other semi-transparent substance, be placed, and accurate negative copies may be taken by leaving it exposed for a sufficient time to the light. The paper becomes black all round the leaf, or other substance exposed, and the other parts are darkened in proportion to the quantity of light admitted through the different parts of the object. The latter must be placed in close contact with the prepared surface, and for this purpose a piece of plate glass should be laid over it. A contrivance, called a reversing, or pressure frame, which we shall describe by-and-by, is generally used; but a plate of glass placed over the object which is laid on the prepared surface will be quite sufficient. The time required to produce a satisfactory impression depends on different circumstances. When, by cautiously sliding the glass to one side, so as to allow a small part of the engraving, or other object, to be raised a little, the picture is found to be sufficiently distinct, it is then immediately fixed by dipping in a strong solution of common salt. By this very simple process, beautiful impressions may be taken from prints, drawings, lace, plants, leaves, flowers, ferns, mosses, feathers, wings of insects, &c. When the objects to be copied are not perfectly

flat, or are unequal in thickness, the thickest parts may be reduced by paring with a sharp knife, and the objects must be strongly compressed against the prepared surface by means which can be varied to suit the convenience of the operator.

Common salt is by no means the best agent for fixing the photogenic drawing. The hyposulphite of soda is now universally used for that purpose; but we have been thus particular in describing the preceding process, because it is that in which the simplest materials are used, and which, therefore, every beginner in the art may very easily practise. Indeed, the process may be still farther shortened by using the nitrate of silver alone for rendering the paper sensitive to light, and then the picture may be perfectly fixed by merely well soaking it in warm water.

When nitrate of silver, common salt, and hyposulphite of soda are used, the following proportions are recommended:—

| | | |
|---|---|---|
| 1. | Nitrate of silver, - - - - - - - | 40 grains. |
| | Distilled water, - - - - - - - | 1 fluid ounce. |
| 2. | Common salt, - - - - - - - | 20 grains. |
| | Water, - - - - - - - - - - - | 4 fluid ounces. |
| 3. | Hyposulphite of soda, - - - - | 1 ounce. |
| | Water, - - - - - - - - - - - | half a pint. |

To prepare the paper, take some flat deal boards, perfectly clean, and pin the paper on these by their four corners, selecting that side of the paper to receive the preparation which presents the most uniform surface. A sponge brush is then dipped into the solution of common salt, and a sufficient quantity is taken up to moisten the surface of the paper without hard rubbing. The paper is then allowed to dry. Any number of sheets may be thus "salted" at a time, and kept in a portfolio for use. To render them sensitive, those which are about to be used are again pinned on the boards, or carefully laid upon folds of white blotting paper, and are washed over with the silver solution, No. 1, which is to be applied with a camel hair pencil, or soft brush of cotton wool. Both in applying the nitrate and the common salt solution, care must be taken to perform the work equally. If a board is used, it is held with the left hand a little inclined, and the operator sweeps the brush from the upper outside corner over the whole of the sheet, removing it as seldom as possible.

Fig. 1.

The lines in the accompanying figure represent the manner in which the brush should be moved, beginning at *a*, and ending at *b*. "On no account," says Mr. Hunt, "must the lines be brushed across, nor must we attempt to cover a spot which has not been wetted by the application of fresh solution to the place, as it will, in darkening, become a well-defined space of a different shade from the rest of the sheet. The only plan is, when a space has escaped our attention in the first washing, to go over the whole sheet with a more dilute solution. It is, indeed, always the safest course to give the sheet two washings."

When the picture has been taken with the paper thus prepared, all the free nitrate of silver must be carefully dissolved out of it, by well washing with pure water; it is then dried, and being spread on a flat board, or other plain surface, is washed over on both sides with a saturated solution of hyposulphite of soda, No. 3. The picture is then again washed, by allowing a small stream of water to flow over it, at the same time dabbing it softly with a piece of soft sponge, till the water passes off perfectly tasteless. This operation should be twice repeated, or even in particular cases performed three times.

The hyposulphite of soda, which was first pointed out by Sir John Herschel, although it was afterwards embraced in Mr. Talbot's patent claims, is decidedly the best fixing agent yet discovered. It is very cheaply manufactured, or may be procured by the photographic amateur in the following manner:—A solution of caustic soda is formed by dissolving a pound of soda in a quart of boiling water, and mixing it while hot with half-a-pound of fresh burnt lime, slaked with another quart of boiling water. The mixed solution is carefully covered from the air till cold, and then the clear liquor is decanted off, and made to dissolve, by boiling, as much sulphur as it will take up. The yellow solution thus formed is now decanted into a deep vessel, and a current of sulphurous acid gas passed through it until it becomes quite colourless. This is done by plunging to the bottom of the vessel the end of a long-beaked retort, in which some linseed oil and sulphuric acid have been mixed. A slight heat is applied, and the sulphurous acid gas, which is then given off in abundance, is rapidly absorbed by the solution in passing through it. In this process the fluid is gradually deprived of its yellow colour; but if it be desired to procure the hyposulphite in a crystallized form, the fluid should be taken and filtered while yet a little yellow, and evaporated in an earthen vessel, to the consistence of a syrup, over a quick fire. It is then mixed and well shaken with half its volume of alcohol. The latter takes up the sulphuret and floats above, while the lower solution, which is the hyposulphite, is left to cool under it. It ought to be carefully excluded from the action of any bright light, and kept in small well-stoppered glass vessels, which it should nearly fill, as the oxygen of the atmosphere tends to precipitate the sulphur, and to change the hyposulphite into a sulphate.

The admirable qualities of the hyposulphite of soda as a fixing agent, have induced us to present our chemical readers with this process, by which, when not otherwise procurable, it may be formed at pleasure; but it will seldom be necessary to take the trouble of making it, as it can generally be easily purchased at two or three shillings per pound. The simple processes thus given are well suited for "copying by application;" that is to say, for copying directly from engravings, or other objects, placed on the prepared paper, without the camera obscura. The student should practise a number of experiments in this department, before he attempts the more delicate manipulations required for the camera. In making these experiments, he will find it convenient to be provided with the copying-frame already alluded to, of which there are different forms. It consists essentially of one or two pieces of thick plate glass, fixed in a wooden frame, with a wedge or screws at the back for pressing the plates together; or, instead of the lower plate, a flat board may be used, covered with two or three folds of flannel. One of the simplest forms of this useful contrivance is represented in the annexed cut.

The most convenient size for the plates is something larger than a single leaf of quarto post writing paper. The glass should be selected as colourless as possible, and more especially must it be entirely free of a yellow or reddish tint, these colours, as shown in Chap. I., obstructing the passage of the most efficient rays. The two accompanying figures represent a front and back view of a very convenient form of the copying frame. Fig. A exhibits it in front, as taking

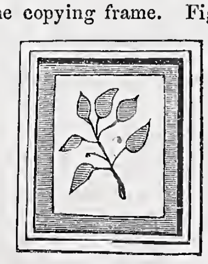


Fig. A.

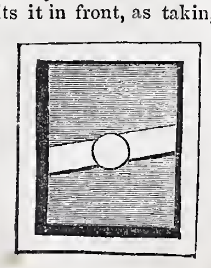


Fig. B.

a copy of leaves; and the other, B, shows the back of the frame, consisting, in this case, of a piece of strong tinned-iron, which presses on a flannel cushion placed between it and the glass, so as to secure the close contact of the paper with every part of the object to be copied. The compression is produced by a brass bar, which is wedged into angular apertures in the sides of the frame. In using this, the frame is

placed face downwards, carefully laying out on the glass the object to be copied, and placing smoothly over it the photographic paper. In arranging botanical specimens, the under surface of the leaves should be next the glass, so that their smooth upper surface may be in contact with the paper. Engravings should likewise be placed with their faces to the prepared side of the paper. The cushion (of flannel or velvet) is then placed on the paper, and over it the wooden or metal back, which is firmly pressed down by the bar or screws. The frame is then reversed and exposed to the light. In strong sunshine, an exposure of a few minutes will generally suffice to produce beautiful copies, but in diffused daylight a considerably longer period will be required.

Very good copies may be taken from dried botanical specimens, but they are far inferior to those from freshly-gathered leaves or plants, in which not only the nerves of the leaves, but the down clothing the stems, and even the most delicate gradations of shades, are copied with inimitable fidelity. All this is done without effort; it is the silent work of an invisible agent, (for, as already shown, it is not the *light*,) which draws with unerring pencil, its "exquisite sketches from nature." "It is so natural," said Mr. Talbot, in his first communication to the Royal Society on this subject in 1839, "to associate the idea of *labour* with great complexity and elaborate detail of execution, that one is more struck at seeing the thousand florets of an *agrostis* depicted with all its capillary branchlets, (and so accurately, that none of all this multitude shall want its little bivalve calyx, requiring to be examined through a lens,) than one is by the picture of the large and simple leaf of an oak or a chestnut. But, in truth, the difficulty is in both cases the same. The one of these takes no more time to execute than the other; for the object which would take the most skilful artist days or weeks of labour to trace or to copy, is effected by the boundless powers of natural chemistry in the space of a few seconds." This was spoken with reference to the copying of objects by the solar microscope, before the discovery of the calotype process, which renders that instrument quite unnecessary, except for affording magnified copies of very minute objects.

"The copying-frame," says Mr. Hunt, "is an indispensable requisite to the photographer; it is used for copying all small objects by transmission, and multiplying the original pictures from nature. It is, indeed, the printing-press of the artist." Its use in multiplying the pictures from nature, or from engravings, leads us to speak, in the next place, of

### NEGATIVE AND POSITIVE PHOTOGRAPHS.

It is obvious, that in copying any object or engraving by the methods above-mentioned, the lights and shadows will be reversed in the copy; those parts being darkest which receive the greatest amount of the solar influence. The pictures thus obtained are light upon a dark ground, and are termed *negative photographs*. To obtain a correct copy of the original, these negative photographs must now be placed in the frame, with their back to the light, and the copies thus obtained will be *positive photographs*—dark upon a light ground, as in the original engraving, or other object to be copied. Any required number of positive photographs may be obtained from one negative copy.

### OTHER PREPARATIONS FOR COPYING.

Following the plan which we have laid down, of proceeding from the simpler to the more complex operations, we have hitherto confined our attention to those photographic surfaces prepared by the nitrate of silver alone, or by the nitrate combined with a solution of common salt, and producing a chloride of silver, which is much more sensitive than the nitrate. We may here observe, that the latter, when used alone, and afterwards fixed (as already described) by simply washing with warm water, ought to be dissolved in the proportion of sixty grains to the fluid ounce of water; although, when used along with the muriate of soda or common salt, the proportion already given is the best, namely, forty grains to the ounce of water. Various other substances may, however, be employed to produce a paper sufficiently sensitive for copying. Instead of the muriate of soda, for instance, the muriate of strontia may be used, in the proportion of thirty-five grains to two ounces of water, with a silver solution of one hundred grains to the ounce. This produces a beautiful and very sensitive paper. The muriate of lime, applied in nearly the same proportions, affords a paper less sensitive, but deepening to a brick red in full sunshine. The muriate of ammonia, or sal-ammoniac—a very common and cheap article of commerce—used in the proportion of two scruples to four ounces of water, and the silver solution in the proportion of sixty grains of the nitrate—forms a very beautiful paper, equalling in sensibility the best kind prepared with the muriate of soda, at nearly one-half its expense, and darkening, when exposed, to a fine chocolate brown. The muriate of iron affords good pictures, but unfortunately they cannot be fixed. The chlorate of potash, with sixty grains of the nitrate of silver to the ounce of water, produces a not very sensitive paper, but some of the specimens prepared in this manner are remarkably beautiful, the ground being a pretty blue or lilac. Solutions of the chlorides of zinc and soda, applied as usual with the nitrate of silver, yield pictures with a deep red ground. The muriatic acid and the aqueous solution of chlorine may likewise be used for converting the nitrate into a chloride, but the muriate of soda or common salt solution is decidedly preferable to either.

The following is the preparation of the paper for the purposes to which we have devoted this chapter, recommended by Mr. Thornthwaite, of London, in his little manual of photography. It is, perhaps, preferable for general use to any of those mentioned, and we shall adopt, with a few verbal alterations, his very minute description of the process. Such details, to insure the success of the beginner, cannot be too minutely explained.

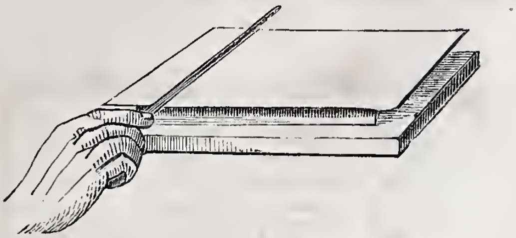
The chemical solutions to which the preference is given are these two:—1st, Ten grains of muriate of baryta dissolved in one ounce of distilled water; 2d, Solution of ammoniacal nitrate of silver, containing about fifty grains of nitrate of silver in the ounce.

The ammoniacal nitrate of silver is prepared in the following manner:—In a two-ounce stopped phial, place 50 grains of crystallized nitrate of silver, and pour over it one ounce of distilled water. When the crystals are dissolved, add, by a few drops at a time, some strong solution of ammonia, taking care that after each addition the phial is well shaken. The mixture becomes at first of a dark brown colour, a precipitate of oxide of silver being formed; but this precipitate is quite dissolved as soon as the proper quantity of ammonia is cautiously added, and the solution becomes perfectly clear. In this state it is ready for use.

The first operation for preparing the photogenic paper consists in applying the solution of muriate of baryta. This may be done with a brush, in the manner already described, or the paper may be carefully laid on the solution, after the latter has been equally distributed on the surface of a horizontal glass plate, or a flat earthen dish. In this case, care must be taken that no air-bubbles remain between the paper and the solution, and also that the back of the paper is not wetted. The edges of the paper have a tendency to curl upwards from the solution by the expansion of the moistened side, but this must be prevented by slight pressure over the back of the paper by means of a glass rod or pencil. When the sheet lies perfectly flat on the solution, and loses its rigidity, becoming at the same time slightly less opaque, this is an indication that enough of the fluid has been absorbed. The sheet may then be raised from the solution, allowed to drain for a few seconds, and hung up to a cross rail of wood by two pins passed through its upper corners into the wood. After a minute or so, the superfluous fluid, which accumulates at the bottom of the sheet, is removed by the application of a piece of thick filtering paper. By renewing from time to time the solution in the glass plate, or dish, any number of sheets may thus be prepared for use.

Another method of applying the solution, is to place the sheet of paper on a wooden board a little smaller than the sheet. A measured quantity of the solution is poured across one end of the sheet, and is carefully distributed over the

whole surface by means of a smooth glass rod, as shown in the annexed cut. A few seconds are allowed for the proper



absorption of the liquid, and the sheet is then hung up to dry as before.

If the surface of the paper be a little greasy, the gentle friction of the rubbing processes, either with a brush or glass rod, tends to insure the proper wetting of the surface, and is therefore, in this respect, preferable to the other method. A little ball of cotton-wool, hooked on the end of a silver wire, by which it is partially drawn into a glass tube, makes a very good brush, and is preferable to any other for applying the nitrate of silver, which rapidly destroys ordinary brushes. The cotton-wool can be changed as often as necessary.

Having applied the muriate of baryta to the paper by either of these methods, an operation which may be performed in the daylight, as the muriate of baryta is not affected by the light, the paper may be kept when dry, without deterioration, for any required length of time. When a sheet is to be used, it is taken and washed over on the same side with the ammoniacal solution of nitrate of silver, applied in the same manner; but in this case it ought to be hung up to dry in a room or cupboard from which the light is excluded. When dry, it should be smoothed with a glass rod, and is now ready for use. If not to be immediately used, it ought to be preserved from the light in a portfolio, or between the leaves of a book; but even with these precautions it soon begins to darken and spoil in this unfixed state, and therefore it should never be finally prepared with the nitrate more than twenty-four hours before use.

With the paper thus prepared, beautiful copies may be taken. The drawing is then to be fixed with the hyposulphite of soda, applied with the following precautions:—One ounce of the hyposulphite is dissolved in one pint of water; and this solution, when about to be used, is poured into a flat dish of sufficient size to contain easily the drawing to be fixed. The latter is first washed for a few minutes in pure cold water, by simple immersion in the water with slight agitation. It is then laid, face upward, on a glass plate, or flat dish, and over it is gently poured some hot water, till the whole of the size of the paper appears to be removed. This is known to be the case when the water is quickly absorbed, and the surface becomes free from running liquid on inclining the dish or glass. A fold or two of white blotting paper, which ought to be perfectly free from lines, is then gently pressed on the surface of the drawing. The latter is now taken and laid on the solution of hyposulphite, *face upwards*, till the whole of its surface appears wetted by the upward absorption of the fluid. The paper is then to be well washed in separate portions of water till the water comes off tasteless. This is a proof that the hyposulphite of silver, formed in the fixing process, and which, when present, communicates to the water a very sweet taste, is entirely removed. The picture is now fixed, and may be dried and exposed to light without injury.

The *rationale* of this, and the other processes mentioned, is the same as when muriate of soda, or common salt, is used. The muriate of barytes, for instance, consists of barytes and muriatic acid. When the nitrate of silver is applied, the nitric acid, one of its proximate elements, combines with the barytes, forming nitrate of barytes, while the silver combines with the chlorine of the muriatic or hydrochloric acid, forming chloride of silver, the substance which is sensitive to the light, or, more properly, to the actinic influence with which the light is accompanied. That mysterious agent acts by reducing the silver; that is to say, by partially separating the chlorine from the silver, which now appears on the paper in the form of a subchloride. Farther exposure to the light, after the picture has been thus formed, would soon reduce the chloride over the whole surface; but this process is arrested at the proper stage by applying the hyposulphite of soda, in which the unreduced chloride is rapidly dissolved, while the subchloride, already reduced by the light, is not affected. The hyposulphite has thus the property of clearing away all that remains of the sensitive ingredient upon the paper; the chloride of silver is converted into a hyposulphite of silver, which is washed away by the water.

We have now said all that appears to be necessary for the instruction of the student or amateur in the simplest and easiest department of this delightful art—a branch of it which may be pursued with the highest gratification, even without the assistance of that very simple instrument, the camera obscura. A copying frame, or one or two plates of thick glass, and a few flat dishes and boards, are all the apparatus required for copying, by these processes, engravings, botanical and entomological specimens, &c. &c. The camera may also be used, but not with good effect, as the surfaces thus prepared are not sufficiently sensitive to yield satisfactory impressions to the image produced by the lens, except when the solar rays are concentrated. We shall describe, in our next chapter, the Calotype or Talbotype process, by which the paper is prepared to a singular degree of sensibility, so as to receive in the camera an almost instantaneous impression. In this process a more elaborate and delicate manipulation is required; and the paper to be used for the purpose will be more carefully selected as the student becomes more fastidious. We shall, therefore, conclude the present chapter with some directions as to the

SELECTION OF PAPER FOR PHOTOGRAPHIC PURPOSES.

This is an important point, whatever be the nature of the processes for which the paper is required. The student may be satisfied at first with comparatively rude and imperfect delineations; but, as he improves in dexterity of manipulation, he will aim at the highest degree of perfection, and this can only be attained by attending to the most minute details; and more especially, as the very foundation of all, to the careful selection of his paper for photographic experiments. As a general rule, select the finest post paper, taking care that it be of a uniform texture, free from spots, and of equal transparency, choosing the oldest rather than the newest varieties. "Experience has proved," says Mr. Hunt, "that recently manufactured paper does not answer equally well with that which has been made for a year or two; and I have found that such as I have selected from the shop-worn stocks of stationers has been generally superior to that which has been more recently manufactured." Unsized paper is not recommended. The solutions employed—especially the silver preparations—ought to be retained as much as possible upon the surface, and this is best secured by using sized paper. It is likewise important that the imbibitions, or the absorption of the liquids into the body of the paper, so far as this proceeds, should be as equal as possible over the whole sheet, and hence the necessity for carefully attending to those little inequalities in texture which we often meet with in the same sheet, and which, when developed to any appreciable extent, render the paper unfit for receiving good photographic impressions. Every sheet should be examined by holding it between the eye and a strong light, either of a window or lamp; and by scanning it carefully in this position, the variations in its texture will be seen by the different quantities of light transmitted through it. The light of a lamp or candle at night, before which the sheet should be moved in different directions, is preferable to daylight for this purpose. Sheets of uneven texture, or those which have specks or watermarks, should be rejected. Each sheet, when approved, should be marked on one side with a pencil, that no mistake may occur in the future application of the solutions. The size most convenient for use is about 9 inches by 8. The blue wove post, manufactured by Whatman, is strongly recommended as an excellent paper for photographic purposes.

# HISTORY.

## CHAPTER XI.

### EXISTING MONUMENTS OF EGYPT.

It seems to us most expedient, after noticing in the succinct manner we have done, the organization of the Persian monarchy, to select one or two of the most interesting of the original states built up into it, as illustrative of the materials out of which the Persian power was constructed. For this purpose we have selected the Egyptians and the Hebrews.

The land of Egypt, properly speaking, is the valley of the Nile, from the lowest cataract upon that river to the sea; *i. e.*, it extends in length, from about the 24° of northern latitude to a little north of the 31°. From the 24°, the latitude of Syene, to the 30°, the latitude of Cairo, or the apex of the delta, the valley of the Nile is bounded by two nearly parallel ranges of hills,—the utmost distance of which from each other never exceeds twenty-four geographical miles. From the 30th degree of latitude the river splits into various branches, which fall, or, in old times, fell into the sea by numerous embouchures. The land of Egypt proper, from the head of the delta, consisted of two narrow stripes of land, one along the eastern bank of the most easterly branch of the river, which fell into the sea about Pelusium, nearly in longitude $32\frac{1}{2}°$ east of Greenwich; the other along the western bank of the most westerly branch, which fell into the sea near Canopus, about longitude $30\frac{1}{3}°$ west of Greenwich; and of the delta included between these two.

What can properly be called the written history of Egypt is compiled in languages which were not the language of the land—the Greek and Hebrew. The earliest Greek writer who gives any account of it—for the incidental allusions in the two Homeric poems can scarcely be taken into our calculations—is Herodotus, who compiled his history several years after Egypt had become a Persian province. In the Hebrew writings we have a few notices of independent Egypt, but the most of them relate to the foreign operations of Egyptian monarchs. None of them furnish us with adequate notions of the civil structure of Egypt; and by far the majority relate to the period when Egypt was at least in the process of being conquered. So old is this land, that it had been a mighty kingdom, and had become a mere tributary province before the commencement of what can properly be called civil history. Its written intelligible annals consist of incidental notices, subservient to telling the story of another state in the Hebrew, and the embodiment of old and perplexed traditions in the Greek.

The monumental sources of Egyptian history must be used with especial caution. Egypt was conquered by Cambyses in the year before Christ 528, and remained a Persian province, with brief and unimportant exceptions, down to the overthrow of the Persian empire. Egypt was erected into an independent kingdom, with a Greek dynasty, by Ptolemy Soter, in the year before Christ 323, and continued in the hands of his descendants till it was incorporated into the Roman empire by Augustus, in the 30th year before Christ. Egypt continued a province of the Roman empire down to the taking of Alexandria, in the year of our Lord 640. Now we have already had occasion to observe, that, under the successive empires of Assyria, Media, Persia, Greece, and Rome, the dominant power not only allowed the natives to retain their original mode of worship, but frequently—either out of superstition, or a politic desire to ingratiate itself with its subjects—bowed and worshipped along with them. The recorded exception to this rule, in the case of Egypt, is Cambyses; and his war with the shrines and idols of the land, although extensive and destructive in its effects, was attributed, even by his own followers, to madness. We are inclined to believe, from subsequent writers, that many of the most costly structures of Egypt were reared during the long period which intervenes between the conquest of Egypt by Cambyses, and the establishment of Christianity in Alexandria as the dominant religion.

There are only two things that can enable us to ascertain the age of a monument. An inscription upon it coeval with itself, or a description of it as erected or as existing at a certain period, by an author whose age is ascertained. In endeavouring to test by these two standards the age of the monuments of Egypt, we are led to the consideration of the remains of the written language (if the epithet be admissible) of old Egypt, which we possess.

Upon all the monuments of Egypt are engraved, and upon the papyri found in its tombs and mummy chests are traced, characters approximating more or less remotely to figures of external objects, arranged in a manner that would of itself lead us to regard them as the written exponents of some language. The testimony of authors who lived while these characters continued to be employed, establishes this conjecture as truth. The most explicit account we have of them is in the writings of Clemens of Alexandria, a Christian writer of the second century of the Christian era. He says, "Those educated by the Egyptians, first learn the method of the Egyptian

HIEROGLYPHIC REPRESENTATION OF THE NAMES OF THOTHMES III.

scribes, which is called epistolographic; secondly, the hieratic (or priestly), which is used by the priestly scribes; and lastly, the hieroglyphic method, of which one kind consists of elementary representations of sounds; the other is symbolical. The symbolical method of writing is either directly by imitation, or metaphorical by analogy; sometimes it is almost bordering on the enigmatical. In the first case they place a circle for the sun, a crescent for the moon; in the other two, they, as suits their convenience, seek to express themselves by many varying allegories." Porphyry, who lived somewhat later, informs us that "the Egyptians had three methods of writing—the epistolographic, the hieroglyphical, and the symbolical. Of these, the hieroglyphical expresses things by imitation (by likenesses of them); the symbolical covertly expresses them by riddles." Herodotus, long prior to either of these writers, had observed that the Egyptians used two kinds of characters—the hieratic (or priestly), and the demotic (or popular). The expressions of none of these writers are very precise; but two points may be inferred from them, that there were two kinds of writing: one employed in the daily business of life, representing elementary sounds by seemingly arbitrary characters; and one employed by the priests, representing bodily objects by representations of them; and things not palpable to sense by arbitrary allegories.

For many ages the hieroglyphics of Egypt were a sealed book, which no man could open; and the key to the mysteries which they concealed, and which at the same time they alone could reveal, has only been discovered of late years. After perplexing the curious and the learned for ages, they have at last been unravelled by the labours of Champollion, Young, Rosellini, Wilkinson, Gliddon, and other investigators. Before the commencement of the present century, little had been done by the researches of travellers and antiquaries, beyond establishing the existence of these interesting remains of antiquity; and the difficulty of deciphering them was increased by the ignorance in which we were left as to the language they were meant to represent. It was not till 1808, that the learned Quatremere showed that the language of ancient Egypt was identical with the Coptic, which ceased to be spoken about a century ago, although it is still used as a dead language in the Coptic Christian liturgies in Egypt. This fact having been ascertained, one great obstacle to the deciphering of the hieroglyphic inscriptions was removed, and the key of these mysterious symbols, so long sought for in vain, was at length discovered, by the accidental disinterment, near Rosetta, of a block of black basalt, which for ages had lain under ground. This interesting monument, which is now deposited in the British Museum, has long been familiar to the public under the name of the Rosetta stone.

This stone was dug up during the occupancy of Egypt by the French troops in the early part of the present century. Engraved on it was an edict of one of the Ptolemies in Greek, implying, among other things, that certain unknown characters upon the same stone were a repetition of the same edict, in what it terms the enchorial (or national) characters, and the sacred or priestly characters. This twofold division evidently corresponds to the double division of Herodotus. Into that division, the threefold division of

Porphyry is easily resolvable—the epistolographic of Porphyry, the demotic of Herodotus, and the enchorial of the inscription. The sacred of Herodotus embrace the representative and allegorical of Porphyry; for every continuous written discourse, even although its staple consist of representations, must connect them by symbolical indications of non-sensuous notions. The information of Clemens must be taken as he gives it: first, boys are taught the epistolographic, and then the sacred characters. In learning these latter, they are taught first the representative, and then the symbolical figures. There is an intimation in the passage of Clemens, of a hieratical character not hieroglyphical. This can only be accounted for as follows:—Close inspection of the clematic characters of different ages, enables us to trace them back with tolerable certainty to contain more frequently used hieroglyphics; it is possible, that in the age of Clemens the priests may have employed for their epistolographic purposes, a more antiquated kind of demotic character, with less of the original hieroglyphic effused; differing, in short, from that in common use, as the modern Roman letter does from the black letter of the middle ages.

Several antiquarians set themselves to decipher the characters on the Rosetta stone. The Greek inscription was explained by the celebrated scholars Porson and Heyne, and ascertained to be a decree of the priests of Egypt, conferring divine honours upon Ptolemy Epiphanes. To our learned countryman, Dr. Thomas Young, however, belongs the merit of having discovered the key to the monumental legends. In the summer of the year 1814, by an attentive and methodical comparison of the three parts of the inscription with each other, he deciphered the whole sufficiently to enable him to send a translation of each of the Egyptian inscriptions to the Society of Antiquaries, distinguishing the contents of the different lines with as much precision as his materials enabled him to do. In the course of his investigation, he was struck by the manifest occurrence of a multitude of characters among the material, which were evidently imperfect imitations of the more intelligible pictures among the distinct hieroglyphics. The name Ptolemy among the hieroglyphics on the other hand, was found to be represented by a number of hieroglyphics enclosed within a cartouche, or border. The bold and felicitous conjecture of Dr. Young, that these hieroglyphics were employed to express the name of Ptolemy, in consequence of the initial letters of the names they represented composing that name, has since been amply corroborated by the investigation of hieroglyphics similarly enclosed in borders, occurring in other inscriptions to which Greek translations were subjoined. The next step in the way of inference was clear. Hieroglyphics were found employed to represent simple articulate sounds; the material characters were evidently rude and hasty indications of hieroglyphics; *ergo*, the elementary characters of the demotic writing were originally mere abbreviations of hieroglyphics; and hieroglyphics, as Clemens had stated, were sometimes used to represent the elements of articulate sound. Pursuing these researches, and diligently inspecting and comparing immense numbers of papyri inscribed with hieroglyphics or demotic characters, some progress was made in ascertaining the collections of hieroglyphics, and the collections of demotic or enchorial characters, which uniformly stand where certain Greek words stand in the appended translations. The collections of characters representing certain ideas were discovered, but no corresponding sounds. The characters, though not meaningless, were voiceless.

Recourse was naturally had to the written remains which we possess of the Coptic language; and evidence had already been given by Quatremere, that this was the language expressed by the hieroglyphics. The oldest monuments of the dialects of that language we possess, are translations of the Scriptures of uncertain date. Athanasius, himself a prelate of the Coptic church, says—"The Coptic language is divided into three dialects; the Coptic dialect of Mizr, the Bahiric, and the Bashmuric; these different dialects are derived from the same language." Arabian authors enumerate the Coptic, Saidic, and Bashmuric dialect. The Saidic of the Arabians corresponds to the Bahiric of the bishop; but Saidic is an Arabic appellation, signifying the Upper. The Bahiric was therefore, in all probability, the dialect of Upper Egypt, called the Thebaid, from its containing the celebrated ruins of Thebes. The Coptic, or, as Athanasius calls it, the Coptic dialect of Mizr, is called by other writers the Memphitic, the city of Memphis being in Lower Egypt, while Thebes is in Upper. Mizr is the Egypt of Scripture: it lies on both sides of the delta, and above it, till where the Thebaid commences. The Bashmuric seems to have been the dialect spoken in the delta, of which the Bensuritic nome, or district, was one of the most important. In two of these dialects, the Thebaic and Memphitic, there are extant manuscript translations of nearly the whole of the Sacred Scriptures, and of the services of the Coptic church. In the Bashmuric, we possess only a few insignificant fragments. In the Memphitic, we have, moreover, the works of some of the early fathers, the acts of the Council of Nice, and the lives of a number of saints and martyrs. The alphabet used in all these manuscripts is a corrupted Greek. The translations are executed at a period considerably posterior to the great body, and all the most important hieroglyphical and enchorial inscriptions, or manuscripts. They are, moreover, full of words adopted from the Greek, and of Greek idioms. The difficulty, under these circumstances, of discovering what Coptic words might be indicated by certain groups of characters is great—almost insurmountable. Dr. Young ascertained, with tolerable certainty, the meaning of some six hundred groups of characters. Among these he recognised one hundred and forty-one Greek words, or phrases, and one hundred and forty-six Coptic words. He established, with tolerable certainty, the characters corresponding to thirty-nine elementary letters. The form of these characters is vague and shifting. They have been traced, however, both in the enchorial and the hieroglyphic writing. He also succeeded in tracing the numerals employed both in the hieroglyphic and enchorial writings, and in particular those employed to express the days of the month.

Since the death of Dr. Young, much has been written and published about hieroglyphics; and the key to this long-lost method of writing having thus been discovered, was successfully applied by the celebrated Champollion to the deciphering of an inscription on an obelisk, found in the island of Philæ, situated high up the Nile. By these laborious investigations, not less than fourteen hieroglyphic characters were elucidated; and subsequent discoveries have gradually enlarged, and at length completed, the Egyptian alphabet, so that we are now in a position to decipher the whole of the pictorial representations which, for many successive generations, were sculptured in mystery and darkness on these interesting remains of antiquity. Bunsen has given us an Egyptian vocabulary, and a complete list of hieroglyphical signs, according to their classes, and arranged in natural order.

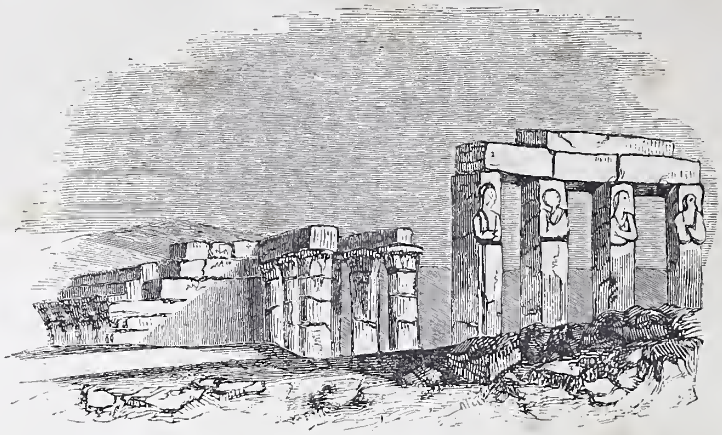
At the same time we must not be led into the supposition that the history of Egypt is yet complete, or even greatly advanced in accuracy, by recent discoveries from hieroglyphic inscriptions. Bunsen and others have done much to advance this work; but the volume is yet lying before us little more than opened. It has to be perused, investigated, and studied; and even then the information derived from it may be unsatisfactory and incomplete. We would not have it to be thought that we undervalue what has been done in this department, or the further information which even a sober and guarded estimate enables us to anticipate. The established transition from the hieroglyphic to the demotic or enchorial character, is most important for the history of written language. We now see, not by vague conjecture, but by demonstration, how the Chinese advanced to their present stage of written language. We see how another nation advanced beyond that stage. It is not unreasonable to expect that we may yet attain to a grammar and dictionary of the language of Egypt as it existed in the time of the Ptolemies, with enough of examples selected from the papyri to show how it was made available for the uses of daily life. This of itself would be an incalculable gain to the history and philosophy of language—to the history of human civilization—to intellectual and moral science; and if we had once attained this point, we might plunge thence into researches regarding the older language and annals of Egypt. But we repeat, that it is above all things important never to overestimate our actual knowledge, never to assume that we know what we do not know, and to go on blindly groping and guessing upon that assumption.

We shall avail ourselves, as we proceed, of what light has been thrown upon Egyptian antiquities by the discoveries of modern Egyptographers. In the meantime we remark, that they have as yet added little positive to what we previously knew regarding the ancient history of Egypt. We are still left to rely much upon the authority of early writers.

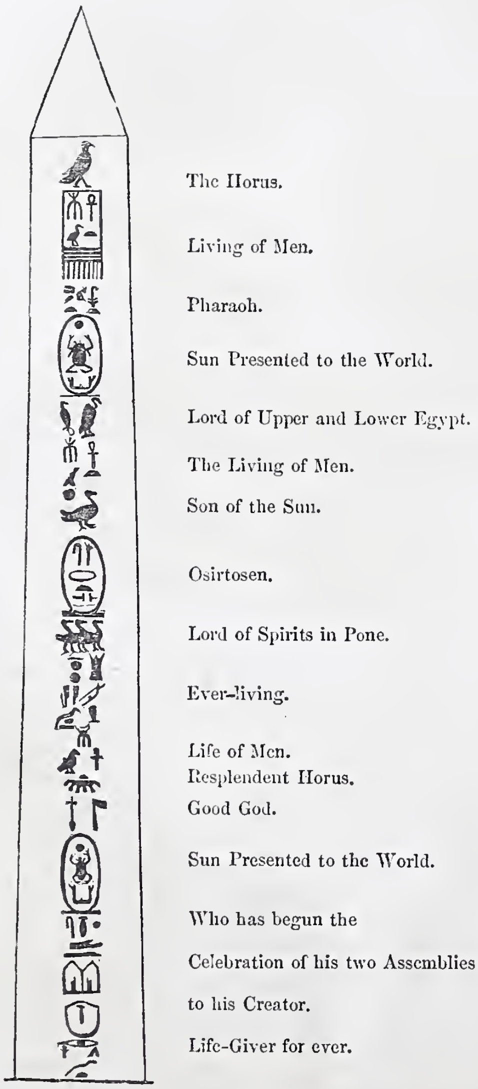
What, then, is the testimony of early writers? What monuments do they enable us to fix upon as undeniably the work of the ancient Egyptians? Herodotus mentions the temple of Heliopolis as existing in his day, such as it had been left by the devastations of Cambyses—shorn of its splendour. He speaks in the same manner of Thebes. He speaks of Memphis with its adjacent pyramids, and of Lake Mœris, and the structures around it, as works of the old time of independent Egypt. Three or four hundred years later, Strabo, who himself visited the country, particularizes these very edifices as of most undoubted antiquity. Herodotus speaks of these monuments as shattered by the frantic excesses of Cambyses; Strabo points to them as having sunk since that time by an insensible de-

cay, while other temples and other cities were flourishing around them. Let us, then, as the groundwork of our inquiries regarding ancient Egypt, impress firmly on our mind the localities and relative position of these places; their remains as they exist in our day; their appearance as described by older writers; the histories or traditions that cling around them.

Heliopolis has its site in the vicinity of Cairo, at some distance from the eastern bank of the eastern branch of the Nile, northward of the termination of the range of hills which from Syene bounds the valley of the Nile on the east. This city was adorned at a very remote period with some of the most splendid temples in Egypt, of which scarcely a ruin remains on the site of their ancient splendour. Its priests were so celebrated for their learning, especially in astronomy, that Heliopolis was visited by strangers for the purpose of profiting by their instructions. Its temples suffered greatly from the brutality and madness of Cambyses, but were still entire and frequented when the city was visited by Strabo, who has given a description of one of them. The largest of these temples was adorned with an avenue of sphinxes, and with several obelisks, two of which had been removed to Rome before he wrote. The obelisk near the church of St. John Lateran in Rome, was brought from Heliopolis by Constantine and his son. It is one hundred and five feet high, and covered with beautiful sculptures. Among the principal remains of the ancient city are some fragments of colossal sphinxes, and an obelisk covered with hieroglyphics. In this obelisk we have a genuine remnant of the independent era of Egyptian history. It is shown in the accompanying illustration, and is connected with the Osirtasens of the 16th dynasty. Being in the city of the sun, it is dedicated to Phré, the sun-god.—(*See " Gliddon's Ancient Egypt," p.* 29.)



THEBES.



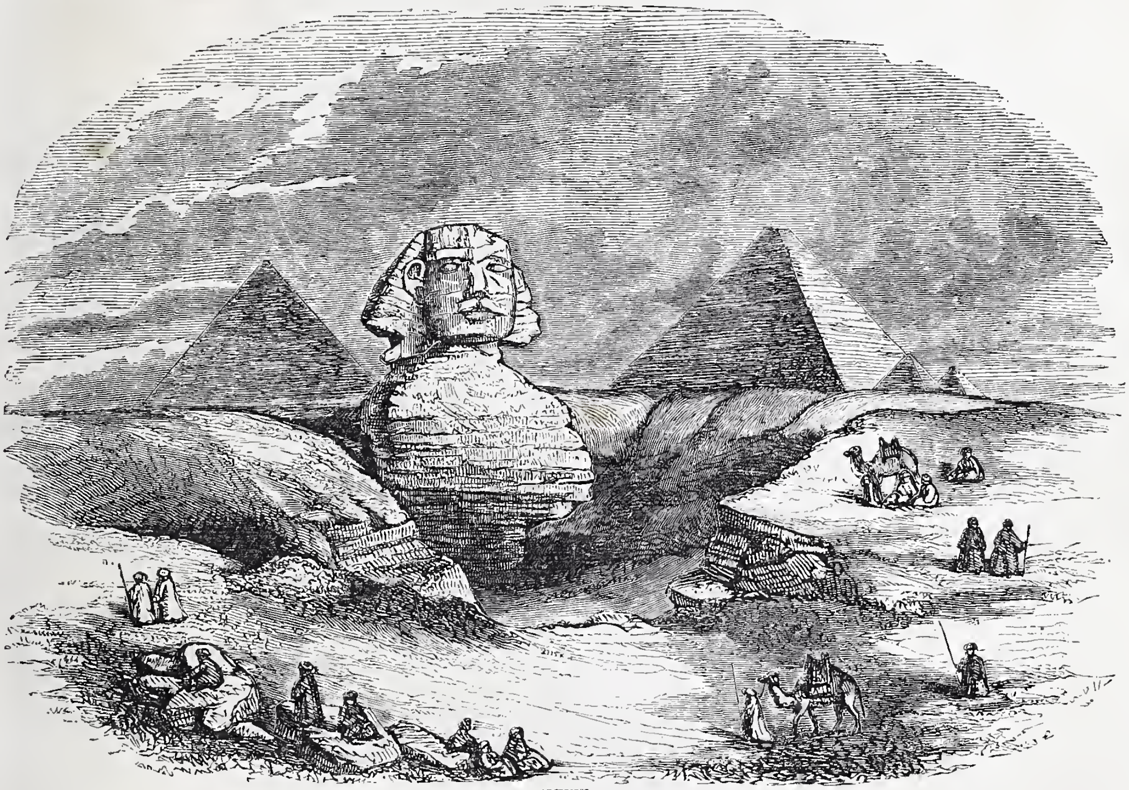

OBELISK.

It is deserving of notice, that Athanasius calls the Coptic dialect spoken in Egypt below the Thebaid, and without the delta, the Coptic of Mizr, and Misraim is the Hebrew name for Egypt. Again, the Egyptian city designated Heliopolis, in the Septuagint version of the prophet Jeremiah, is called On in the Hebrew; and it will be in the recollection of the reader, that Pharaoh is said, in the book of Genesis, to have given Joseph the daughter of the priest of On to wife. This is a coincidence that will afford ground for an important inference hereafter.

Memphis, we are told by Strabo, was situated three *schœni* (22½ miles) above the apex of the delta, on the western shore of the Nile. The measure used by Herodotus is different, but the amount is the same. Here also was a temple, dedicated to a divinity whom the Greeks called Hephaistion. Both Homer and Strabo make mention of the avenue of sphinxes which led to this temple, as to all Egyptian temples. Both make mention of the neighbouring pyramids; Strabo fixing them at the distance of forty stadia from the city. The pyramids are there exactly as Herodotus and Strabo describe them —on the ridge of a rising ground, such as specified by the latter; but at the distance of forty stadia, thence we look in vain for the city of Memphis. The regal buildings, which stood on a rising ground, and stretched down to the grove and artificial lake fed from the waters of the Nile, have not left a trace behind. Between this spot and the pyramids, one solitary sphinx remains of the long colossal avenue. But the mummy pits all around tell what a dense population must for ages have congregated there—must have lived and died, and been deposited in these pits before antiquity began. Strabo speaks of Memphis as, even in his day, second in population only to Alexandria, and as equalled in population only by one other city in Upper Egypt. A few Arab villages are all the haunts now of that once busy emporium; and upon their little fields, the desert sand, which has already overwhelmed On or Heliopolis, seems to gain year after year. The three pyramids of Djizzeh and the sphinx, are unquestionable monuments of old independent Egypt. The mummy pits may—must contain tenants deposited there in later days; but their original form, and the mode of preparing the body for being deposited in them, are relics of the same old Egypt.

Strabo tells us, that immediately above the *nome* or territorial division of Egypt in which Memphis stood, on the left bank of the river, was the Heraclitic nome; and that westward from this latter towards Lybia (or Africa) was the Arsanetic nome. Pliny says there were two Arsanetic nomes; the one behind the Heraclitic nome, as Strabo describes it; the other behind the nome in which Memphis stood, extending down to the valleys of natron (or soda), which run

at nearly right angles to the most westerly branch of the Nile, and gave name to the Nitocritic nome. These statements are easily reconcilable. It is far from improbable, that the extensive tract inland from the upper termination of the Heraclitic nome to the valleys of natron, may have been one district in the days of Strabo, and may have been divided in the time of Pliny into two, for the greater convenience of the authorities, or (for even in those days such things were) to increase the patronage at the disposal of the government of Egypt. In the uppermost, then, of the two Arsanetic nomes, there is a gap in the range of mountains which runs along the western or African side of the valley of the Nile. Here we are told was a lake called Mœris, of prodigious extent, and, according to the Greek writers, artificial. Temples are mentioned as existing on its banks. But the most important structure described as existing here was the Labyrinth. Herodotus mentions it in exaggerated terms, and speaks of it as one of the unquestionable relics of old Egypt. Strabo, in speaking generally of the structure, uses almost the same exaggerated phrases; but when he comes to describe it, the marvellous disappears. It was a structure of stone, supported by pillars and roofed with stone. It contained, says Strabo, as many halls as there are districts in Egypt, all communicating with each other, and being the resort, at certain seasons for certain common purposes, of the delegated authorities from all those districts. This hint is of importance, as bearing upon the mutual relation of the different parts of Egypt, and throwing light upon the old constitution of the country. Belzoni is the only modern who gives us an account of the present appearance of the district, the position of which is so clearly fixed by Strabo and Herodotus. His visit was a hurried one, and his researches necessarily imperfect. From what he saw, however, he considers the ruins as quite bearing out the glowing terms in which Strabo and Herodotus speak of their former huge and impressive character. These also may be considered as undoubted monuments of ancient Egypt, although more full and accurate accounts of their present condition are much needed.



SPHINX.

The fourth locality we mentioned was the city of Thebes—the hundred-gated Thebes—the fame of which had reached Greece even in the early days of the Homer of the Iliad. Herodotus describes the city as having been laid waste by Cambyses, and its fame destroyed, but as still inhabited. Strabo speaks of it in a manner almost exactly descriptive of its present condition. He says that the city had extended in length and breadth ten miles either way, and that it had stood on both sides of the river. He adds, that on the one side of the Nile stood some temples, on the other the Memnon, and the remains of two colossal statues, and that the inhabitants dwelt around them in villages. In the same manner the most recent visitors describe them. He mentions the tombs of the kings in the mountain-glen behind the Memnonium: they are there to this day. These also are genuine relics of old Egypt. So are the temples of Luxor and Karnak on the eastern bank of the Nile; the Memnonium and the more than colossal statues near it. Strabo has described the arrangement of an Egyptian sanctuary. The ruins of Karnak are the only remains in Egypt of which we have documentary evidence, that they belong to the time when Egypt was an independent state, in which we can still trace all the details. First, we have the course or approach, with its row of colossal sphinxes on either side; then came four huge gateways, one after another; last of all is the fane or temple itself. Again, the tombs of the kings—the places of royal sepulture—are as little likely to contain ornaments of a later day, as any place that can be imagined. Sacrilege might destroy their ornaments, but reverence and affection would scarcely decorate them with foreign ornaments in after ages, unless they had become objects of superstitious worship, which these never did. My object for insisting upon this point is—Herodotus makes mention of painters as well as statuaries in his account of Egypt; but this was generations subsequent to the time when Egypt became a Persian province. The paintings on the walls of tombs, of which we find no historical record, may have been the workmanship of the age of Herodotus, or later; some of them doubtless are. But the paintings in the tombs of Thebes are of the age when independent monarchs reigned over that city, and were buried in the valley behind.

Still ascending the Nile, we arrive at the ruins of Edfu, the Appollonopolis Magna of the Greeks, standing on the western side of the river, and about two miles from the water's edge. The sculptures here are executed in the most perfect style of Egyptian art; and none of the remains in Egypt give a juster notion of the distribution of their temples.

Pursuing our course southward towards Nubia, and just before reaching the cataracts of the Nile, we arrive at a small island, called by the ancients Elephantina, where heaps of rubbish mark the site of the town; and there are the remains of two temples, covered, like most

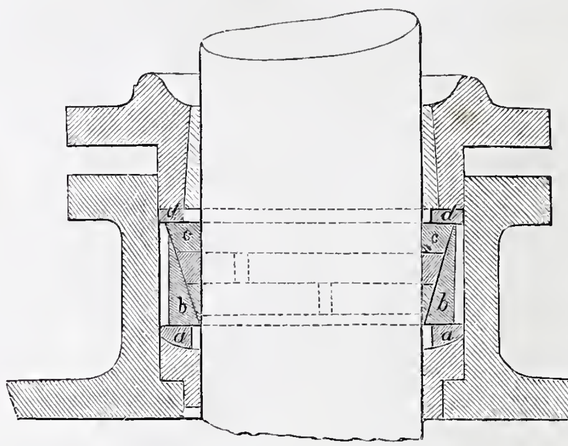
of the public buildings in Egypt, with hieroglyphics, but approaching in their form and plan to the earliest temples of Greece. Still more celebrated for its ruins is another small island, above the cataracts, and occupying almost the southern frontier of Egypt, where the river emerges from Nubia. Here we find the island of Philæ, about six miles to the south of Syene, and nearly thirty-four to the north of the Tropic of Cancer. The whole of this island, with an area of barely 900 yards in circumference and 100 in breadth, is covered with temples in the largest groups and highest state of preservation of any now remaining in Egypt. A view of this magnificent "Isle of ruins"—the Iona of the "land of the Nile"—is given in the annexed plate, from which the reader will be able to form some conception of its grandeur; and let him remember that these august remains are hallowed by the "dim religious light" of a very remote antiquity. No human pen, except the mysterious hieroglyphic tracery engraved on the walls, has left us any record of the origin or subsequent annals of these mysterious structures. They stand in sublime grandeur, bearing, written around them, their own chronicles; and yet in characters so ancient and abstruse, that hitherto the visitor has looked on them with awe as sealed and silent symbols; and only within the last few years has the key been found to unlock their profound secrets. One of the names by which the island is at present known is Jeziret-el-birba, or the Temple Island, a name finely expressive of its character to this day. It is really an island of temples, which are built of bright sandstone, while the cliffs of the island itself are of dark granite, finely contrasting with the mass of ruined structures resting upon them. It is a remarkable circumstance, that nearly the whole island is cased with walls of hewn stone. The labour expended upon it must have been altogether prodigious. It was believed to have been the burial-place of Osiris, and one of the magnificent temples, with which the island is adorned, is said to have been built by Isis in honour of her husband. The small temple of Isis is on the right, and southernmost of all is the great temple of Isis, in front of which are two colonnades, with as many obelisks and pylons, or portals, of huge dimensions. Near the small temple of Isis is an isolated, unfinished building, supposed to have been erected for the worship of the same deity. The pylons or portals of the great temple are richly ornamented with sculpture and hieroglyphics; and when it is considered that one side alone of the great pylon measures 5,400 square feet, and that all of them are entirely covered with hieroglyphics, some idea may be formed of the vast amount of labour expended in forming these inscriptions, which seem to relate chiefly to the service of the gods to whom the temple was dedicated. Near the water's edge, at some distance from these temples, is a large hall, the walls of which are covered with sculptures relating to the death of Osiris; and on the left of the great temple of Isis there is an uncovered enclosure, formed by a colonnade, of which the intercolumniations are filled up to more than one-third of their height. This has been considered as an unfinished temple, and before it lay a small obelisk of granite, little injured, and covered with hieroglyphics, besides a Greek inscription. The latter has been carefully deciphered, and affords one of the most striking records of antiquity hitherto found in Egypt. It bears to be a petition from the priests of Isis at Philæ, to Ptolemy Euergetes II., in 125 or 126 B.C., praying that monarch to release them from the exactions of the military officers and magistrates stationed in the Thebais, and to allow them to erect an obelisk in commemoration of his beneficence in granting this request. The fact that the prostrate obelisk exists to this day, not only shows that the request had been granted, but also that Ptolemy had his reward in the commemoration of his name in connection with this act of beneficence to a distant day. We are not aware that the hieroglyphics have yet been deciphered, but they have been faithfully copied, and, in all probability, they will be found to relate to the same interesting transaction.

It must be admitted, however, that these hieroglyphic inscriptions, and especially those of Philæ, reflect, as far as hitherto studied, but little important light on history. The obelisk at Heliopolis, the three pyramids at Djizzeh, and the neighbouring sphinx, the remains in the Arismaitic nome, and the temples, statues, and tombs at Thebes, these are the beacons that rise in the almost trackless waste of Egyptian history to guide the inquirer's path. By their aid, with a critical investigation of what is written in Greek and Hebrew annals, aided by what light the recent discoveries in hieroglyphical literature throw upon the subject, and the Greek translations found in some of the papyri, we shall endeavour, in next chapter, to reconstruct, as well as we can, the history of independent Egypt—not the air-empty catalogue of names of kings, but the history of civil society as it existed in that wondrous period. The age of the Pharaohs is the earliest era of civilization, and all around was darkness and barbarism, when upon the land of Egypt alone the day-star of human progress had begun to shine.

## COPELAND'S PATENT METALLIC PACKING.

Our readers are aware that metallic packing is now generally used for the pistons of steam-engines, and its application to the "disc engine," by Bishopp, is described in our account of that invention (p. 448). The value attached to this improvement, on its first introduction, might have been expected to suggest the application of the same principle to packings generally; and the use of sheet-brass lining, inside the ordinary hemp-packing, has been proposed. We are not aware that this method has been tried; but any plan which dispenses entirely with the use of hemp seems to be preferable, and this is the principle of the "metallic packing," for which Mr. Copeland has lately taken a patent.

The annexed engraving represents a section of a piston-rod stuffing-box, fitted with metallic packing on Mr. Copeland's

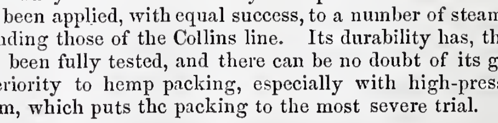



system. It consists of rings of composition metal, of a conical form on the exterior, and fitted into a matrix of wrought or cast-iron. *a a* is a ring of composition, fitted to the bottom of an ordinary stuffing-box, to obtain a plane surface; *b b* is the matrix, and *c c c* the packing rings, cut to allow of their contraction as they wear, and placed so as to break joint. Another ring of composition, *d d*, on which the gland bears to press down the packing rings, is placed over them. The metal of the rings is composed of 9 parts of tin, and 1 of copper. The matrix and rings are of rather smaller diameter than the inside of the stuffing-box, for the purpose of allowing the packing to move, so as to adapt itself to any irregularity in the parallel motion or guides of the piston-rod cross-head.

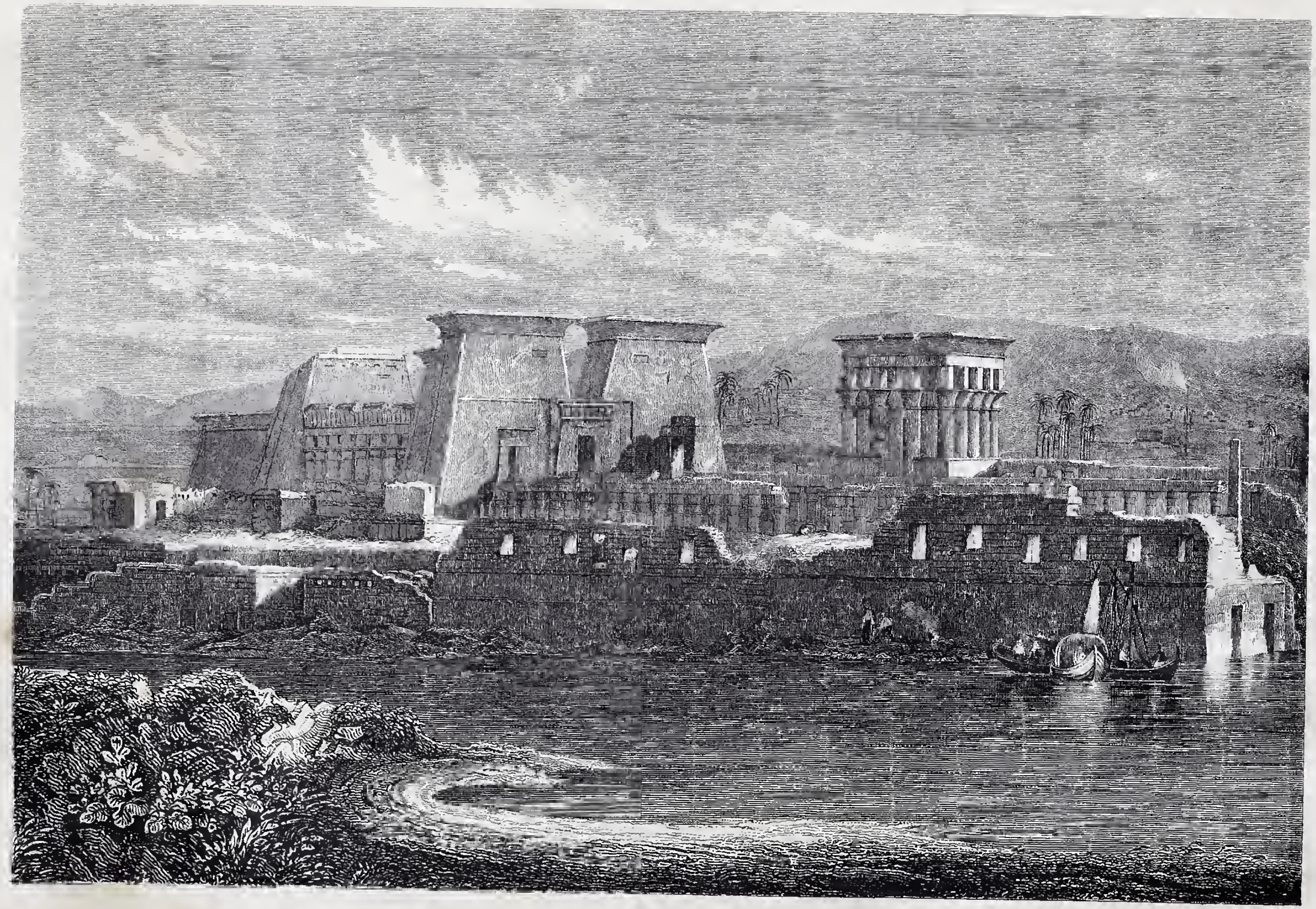
This packing has been patented in the United States by Messrs. Allen & Noyes, and has been in use for three years on the Albany and Boston Railway with perfect success. It has also been applied, with equal success, to a number of steamers, including those of the Collins line. Its durability has, therefore, been fully tested, and there can be no doubt of its great superiority to hemp packing, especially with high-pressure steam, which puts the packing to the most severe trial.

## KEY FOR STEAM-ENGINE CONNECTING-RODS.

The diagram annexed shows the plan of a jib and key; it is not strictly new, the same principle having been long employed in ad-




justing moveable parts of small machinery by setting screws. It requires no other explanation than that the screw, A, secures the key when it is adjusted, and the nut, B, prevents the slackening of the screw.



THE RUINED TEMPLES AT PHILÆ.

EGYPT.

# TABLE FOR FINDING THE DIAMETER OF THE PITCH CIRCLE OF ANY TOOTHED WHEEL OF LESS THAN 301 TEETH,

## OR OF THE RATIO BETWEEN THE SIDE OF ANY EQUILATERAL POLYGON UNDER 301 SIDES, AND THE DIAMETER OF ITS CIRCUMSCRIBED CIRCLE.

| No. of Sides. | Diameter. | No. of Sides. | Diameter. | No. of Sides. | Diameter. | No. of Sides. | Diameter. | No. of Sides. | Diameter. | No of Sides. | Diameter. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 1·1547 005 | 53 | 16·8803 072 | 103 | 32·7910 023 | 153 | 48·7048 350 | 203 | 64·6194 863 | 252 | 80·2161 691 |
| 4 | 1·4142 136 | 54 | 17·1984 340 | 104 | 33·1092 633 | 154 | 49·0231 226 | 204 | 64·9377 835 | 253 | 80·5344 708 |
| 5 | 1·7013 016 | 55 | 17·5165 673 | 105 | 33·4275 252 | 155 | 49·3414 106 | 205 | 65·8926 760 | 254 | 80·8527 725 |
| 6 | 2·0000 000 | 56 | 17·8347 070 | 106 | 33·7457 881 | 156 | 49·6596 988 | 206 | 65·5743 784 | 255 | 81·1710 743 |
| 7 | 2.3047 649 | 57 | 18·1528 527 | 107 | 34·0640 518 | 157 | 49·9779 873 | 207 | 65·8926 760 | 256 | 81·4893 762 |
| 8 | 2·6131 259 | 58 | 18·4710 041 | 108 | 34·3823 163 | 158 | 50·2962 761 | 208 | 66·2109 737 | 257 | 81·8076 781 |
| 9 | 2·9238 044 | 59 | 18·7891 608 | 109 | 34·7005 817 | 159 | 50·6145 651 | 209 | 66·5292 715 | 258 | 82·1259 801 |
| 10 | 3·2360 680 | 60 | 19·1073 226 | 110 | 35·0188 479 | 160 | 50·9328 544 | 210 | 66·8475 695 | 259 | 82·4442 822 |
| 11 | 3·5494 655 | 61 | 19·4254 893 | 111 | 35·3371 149 | 161 | 51·2511 440 | 211 | 67·1658 676 | 260 | 82·7625 843 |
| 12 | 3·8637 033 | 62 | 19·7436 606 | 112 | 35·6553 827 | 162 | 51·5694 338 | 212 | 67·4841 657 | 261 | 83·0808 865 |
| 13 | 4·1785 815 | 63 | 20·0618 363 | 113 | 35·9736 512 | 163 | 51·8877 238 | 213 | 67·8024 640 | 262 | 83·3991 887 |
| 14 | 4·4939 592 | 64 | 20·3800 162 | 114 | 36·2919 204 | 164 | 52·2060 141 | 214 | 68·1207 624 | 263 | 83·7174 910 |
| 15 | 4·8097 343 | 65 | 20·6982 002 | 115 | 36·6101 903 | 165 | 52·5243 046 | 215 | 68·4390 609 | 264 | 84·0357 933 |
| 16 | 5·1258 309 | 66 | 21·0163 879 | 116 | 36·9284 610 | 166 | 52·8425 954 | 216 | 68·7573 595 | 265 | 84·3540 957 |
| 17 | 5·4421 912 | 67 | 21·3345 793 | 117 | 37·2467 323 | 167 | 53·1608 864 | 217 | 69·0756 583 | 266 | 84·6723 982 |
| 18 | 5·7587 705 | 68 | 21·6527 742 | 118 | 37·5650 042 | 168 | 53·4791 777 | 218 | 69·3939 571 | 267 | 84·9907 007 |
| 19 | 6·0755 338 | 69 | 21·9709 724 | 119 | 37·8832 768 | 169 | 53·7974 691 | 219 | 69·7122 560 | 268 | 85·3090 033 |
| 20 | 6·3924 532 | 70 | 22·2891 738 | 120 | 38·2015 500 | 170 | 54·1157 608 | 220 | 70·0305 550 | 269 | 85·6273 059 |
| 21 | 6·7095 061 | 71 | 22·6073 782 | 121 | 38·5198 238 | 171 | 54·4340 526 | 221 | 70·3488 541 | 270 | 85·9456 086 |
| 22 | 7·0266 742 | 72 | 22·9255 856 | 122 | 38·8380 982 | 172 | 54·7523 447 | 222 | 70·6671 533 | 271 | 86·2639 113 |
| 23 | 7·3439 422 | 73 | 23·2437 958 | 123 | 39·1563 732 | 173 | 55·0706 370 | 223 | 70·9854 527 | 272 | 86·5822 141 |
| 24 | 7·6612 976 | 74 | 23·5620 087 | 124 | 39·4746 488 | 174 | 55·3889 295 | 224 | 71·3037 521 | 273 | 86·9005 169 |
| 25 | 7·9787 298 | 75 | 23·8802 242 | 125 | 39·7929 249 | 175 | 55·7072 222 | 225 | 71·6220 515 | 274 | 87·2188 198 |
| 26 | 8·2962 298 | 76 | 24·1984 422 | 126 | 40·1112 015 | 176 | 56·0255 151 | 226 | 71·9403 511 | 275 | 87·5371 227 |
| 27 | 8·6137 901 | 77 | 24·5166 625 | 127 | 40·4294 787 | 177 | 56·3438 081 | 227 | 72·2586 508 | 276 | 87·8554 257 |
| 28 | 8·9314 043 | 78 | 24·8348 852 | 128 | 40·7477 563 | 178 | 56·6621 014 | 228 | 72·5769 506 | 277 | 88·1737 287 |
| 29 | 9·2490 666 | 79 | 25·1531 101 | 129 | 41·0660 345 | 179 | 56·9803 949 | 229 | 72·8952 504 | 278 | 88·4920 318 |
| 30 | 9·5667 722 | 80 | 25·4713 371 | 130 | 41·3843 132 | 180 | 57·2986 885 | 230 | 73·2135 504 | 279 | 88·8103 350 |
| 31 | 9·8845 170 | 81 | 25·7895 661 | 131 | 41·7025 923 | 181 | 57·6169 823 | 231 | 73·5318 504 | 280 | 89·1286 382 |
| 32 | 10·2022 972 | 82 | 26·1077 971 | 132 | 42·0208 719 | 182 | 57·9352 763 | 232 | 73·8501 505 | 281 | 89·4469 414 |
| 33 | 10·5201 097 | 83 | 26·4260 300 | 133 | 42·3391 520 | 183 | 58·2535 712 | 233 | 74·1684 507 | 282 | 89·7652 447 |
| 34 | 10·8379 514 | 84 | 26·7442 648 | 134 | 42·6574 325 | 184 | 58·5718 648 | 234 | 74·4867 510 | 283 | 90·0835 480 |
| 35 | 11·1558 201 | 85 | 27·0625 013 | 135 | 42·9757 134 | 185 | 58·8901 593 | 235 | 74·8050 514 | 284 | 90·4018 514 |
| 36 | 11·4737 132 | 86 | 27·3807 395 | 136 | 43·2939 948 | 186 | 59·2084 540 | 236 | 75·1233 518 | 285 | 90·7201 548 |
| 37 | 11·7916 290 | 87 | 27·6989 794 | 137 | 43·6122 765 | 187 | 59·5267 488 | 237 | 75·4416 524 | 286 | 91·0384 582 |
| 38 | 12·1095 656 | 88 | 28·0172 209 | 138 | 43·9305 587 | 188 | 59·8450 438 | 238 | 75·7599 530 | 287 | 91·3567 617 |
| 39 | 12·4275 213 | 89 | 28·3354 639 | 139 | 44·2488 413 | 189 | 60·1633 389 | 239 | 76·0782 536 | 288 | 91·6750 653 |
| 40 | 12·7454 948 | 90 | 28·6537 083 | 140 | 44·5671 243 | 190 | 60·4816 342 | 240 | 76·3965 544 | 289 | 91·9933 689 |
| 41 | 13·0634 848 | 91 | 28·9719 543 | 141 | 44·8854 076 | 191 | 60·7999 297 | 241 | 76·7148 552 | 290 | 92·3116 725 |
| 42 | 13·3814 900 | 92 | 29·2902 016 | 142 | 45·2036 914 | 192 | 61·1182 253 | 242 | 77·0331 561 | 291 | 92·6299 762 |
| 43 | 13·6995 094 | 93 | 29·6084 503 | 143 | 45·5219 755 | 193 | 61·4365 211 | 243 | 77·3514 571 | 292 | 92·9482 799 |
| 44 | 14·0175 420 | 94 | 29·9267 002 | 144 | 45·8402 599 | 194 | 61·7548 170 | 244 | 77·6697 582 | 293 | 93·2665 837 |
| 45 | 14·3355 870 | 95 | 30·2449 515 | 145 | 46·1585 447 | 195 | 62·0731 130 | 245 | 77·9880 593 | 294 | 93·5848 875 |
| 46 | 14·6536 435 | 96 | 30·5632 039 | 146 | 46·4768 299 | 196 | 62·3914 092 | 246 | 78·3063 605 | 295 | 93·9031 914 |
| 47 | 14·9717 109 | 97 | 30·8814 375 | 147 | 46·7951 154 | 197 | 62·7097 054 | 247 | 78·6246 618 | 296 | 94·2214 952 |
| 48 | 15·2897 883 | 98 | 31·1997 123 | 148 | 47·1134 012 | 198 | 63·0280 020 | 248 | 78·9429 631 | 297 | 94·5397 991 |
| 49 | 15·6078 752 | 99 | 31·5179 682 | 149 | 47·4316 873 | 199 | 63·3462 985 | 249 | 79·2612 645 | 298 | 94·8581 031 |
| 50 | 15·9259 711 | 100 | 31·8362 252 | 150 | 47·7499 737 | 200 | 63·6645 953 | 250 | 79·5795 660 | 299 | 95·1764 072 |
| 51 | 16·2440 754 | 101 | 32·1544 832 | 151 | 48·0682 605 | 201 | 63·9828 922 | 251 | 79·8978 675 | 300 | 95·4947 112 |
| 52 | 16·5621 876 | 102 | 32·4727 428 | 152 | 48·3865 476 | 202 | 64·3011 892 | | | | |

The first column contains the number of sides of a polygon, or the number of teeth of a wheel; and the second the corresponding diameter of the circumscribed or primitive circle, reckoning the side or pitch unity. Hence, the diameter for any other side or pitch, is found by multiplying the diameter given in the table by the given side or pitch; and, conversely, the side or pitch is found by dividing the given diameter by that found in the table.

The table is calculated to the nearest unit in the seventh place of decimals; but, in general, the result will be obtained with sufficient accuracy by using only the first four; in which case the fourth decimal figure ought to be increased by unity when the value of those that follow is more than ·00005.

The following approximation may be found useful, and is more accurate than that generally used. Above ten teeth, it gives the diameter correct to the nearest unit in the third decimal place—and, as the number of teeth increases, the approximation becomes much closer.

Let $n$, $d$, and $p$, be the number of teeth, diameter, and pitch of a wheel, then

$$d = \left\{ \cdot 3183\, n + \frac{\cdot 5236}{n} \right\} p.$$

# KIRCHENER'S DENDROMETER.

*Fig.* 1.

The specific use of this instrument is to ascertain the height and diameter of trees, but it may of course be applied in finding the dimensions of all similar objects. It is represented by the engravings above—of which fig. 1 is a side view of the instrument; fig. 2 an end view of it; and fig. 3 represents it in plan.

When applied to use, the instrument is mounted on a stand which receives its lower extremity *a*. The box *b* contains a tape-line *c*, which, when not in use, is coiled round a pivot in the centre by a handle attached to it. To proceed with the operation, the tape-line is connected by a ring on the end of it to a screw *d* (shown separately by figure 4), which is previously screwed into the body of the tree to be measured, at such a height as that the tape, when extended, may be horizontal. Having thus attached the end of the line, the operator falls back from the tree, carrying with him the instrument, and of course unwinding the tape till it is drawn out full length. Here he places the instrument; and he next marks by a chalk-line the particular point of the tree at which it ought to be cut. Upon this point the sight *e* is brought to bear, the slot *f* in the end of the sight (seen in fig. 2) covering the mark. This adjustment is managed by means of the pinion *h* and sector *i*,—the former being turned by the handle *g* on the same axis. If the tree incline to either the right or the left, or if otherwise not perfectly straight, the same inclination is given to the instru-

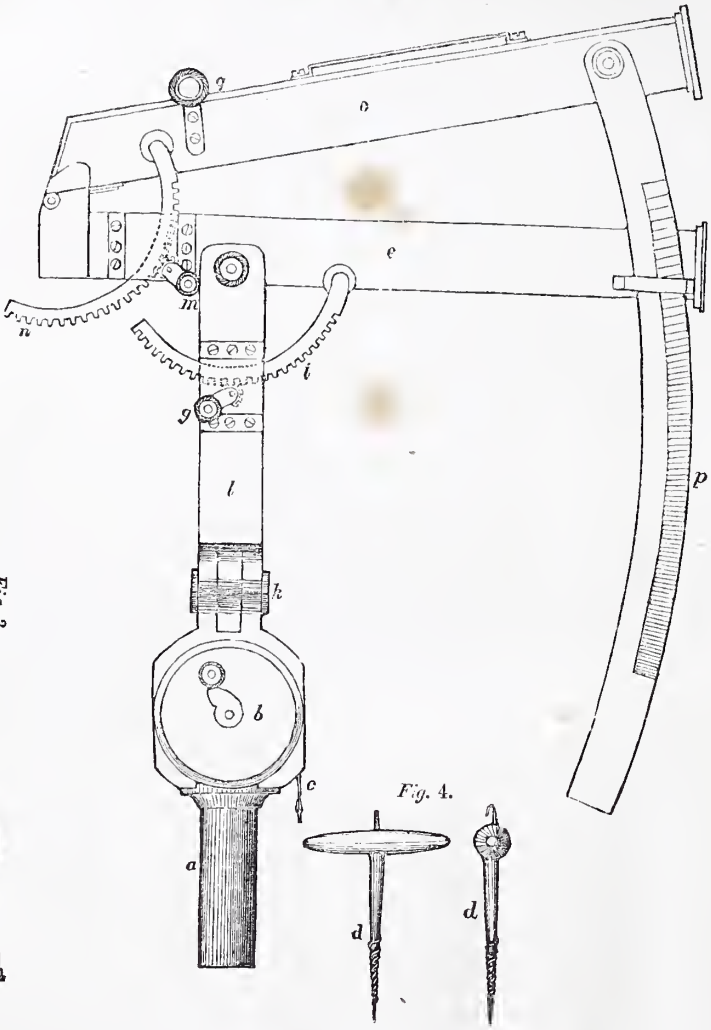



*Fig.* 2.

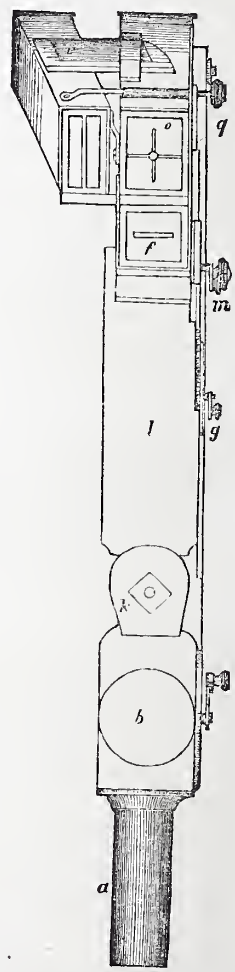



*Fig.* 3.

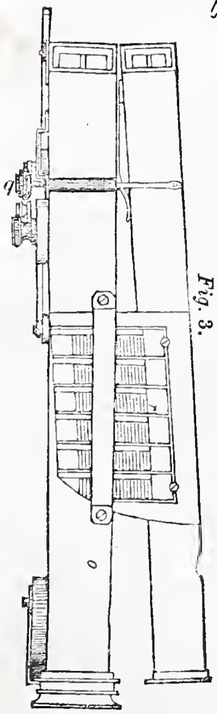



*Fig.* 4.

ment by simply turning it on the double joint *k*. Another joint *l*, immediately above this, is for the same purpose.

The next step is to take the bearing of the trunk of the tree immediately under the first branch. This is effected by means of the upper sight *o*, which is wrought in the same manner as the under one by a handle *m* working a pinion and sector *n*, and adjusted also by the cross-slots at the end (seen in fig. 2). The height of the trunk will be indicated upon the graduated limb *p*.

To determine, in the next place, the diameter of the tree, it will be observed that the upper sight has a third one jointed laterally to it. Having therefore set the two branches respectively to the right and left outlines of the tree, the diameter of it will be indicated in inches upon the graduated table *r* (seen in fig. 3).

In conformity with the customary practice in commerce, wood-merchants take the diameter of the tree at half its height, and upon that principle this instrument has been constructed, and also the table calculated. For example, one may suppose the limb *p* had given 50 feet for the height, and 26 inches for the diameter of the tree. In this case, after having measured the height, the two sights *o* are lowered together by means of the handle *m* till they arrive at 25 feet, or half the height, as indicated by the limb, and at this altitude the diameter, 26 inches, is taken. The table *r* indicates also the solid contents

of the trunk, and it is found that a trunk, 50 feet high, by 26 inches diameter, contains nearly 187⅞ cubic feet.

To ascertain the exact diameter of the tree, M. Kirchener has arranged the table in five columns. As the table gives the capacity of trunks from 1 to 50 feet high, each column respectively contains the results for every 10 feet of height. Accordingly, the half height, 25 feet, in the preceding example, is found in the third column.

As it seldom occurs that a tree increases as much as one inch in diameter for every ten feet of length, the tablo takes no account of fractional dimensions.

## TAIT'S PORTABLE DIORAMA.

An ingenious portable diorama, constructed by George Tait, Esq., advocate, F.R.S.S.A., was exhibited by that gentleman to the Royal Scottish Society of Arts, in November, 1841, and April, 1842. This diorama, which was honoured with the Society's medal, could be viewed by only one or two persons at a time, the pictures being *within the box*, and being seen through eyeholes. Subsequently, Mr. Tait made a diorama having the construction modified, so that it might be viewed by a number of persons at a time, the pictures being placed *upon the front of a box*, where they are exposed uncovered. The front light is thrown upon them from without, and the back light from within, the box; and both may be increased or diminished at pleasure. Gas is the most convenient light; but oil may be employed, by adopting means for properly increasing or diminishing the light upon the pictures. The apparatus is used in a dark apartment; and ought to be so placed, that the horizon of the pictures may be on a level with the eye.

The following side elevation and plan represent a small diorama made upon this principle:—

Fig. 1.

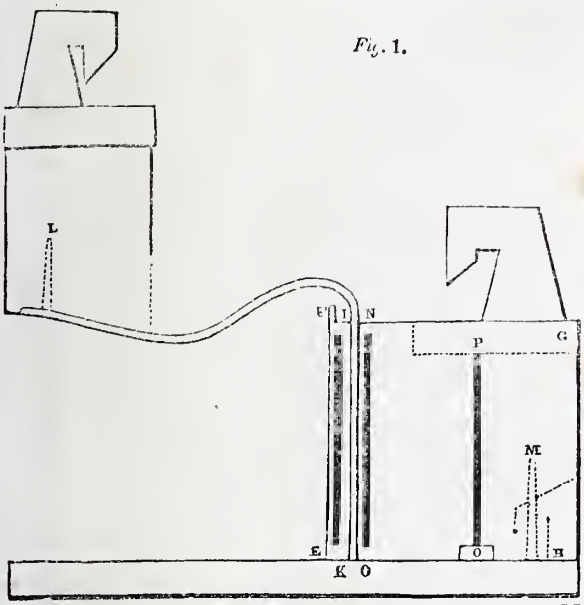
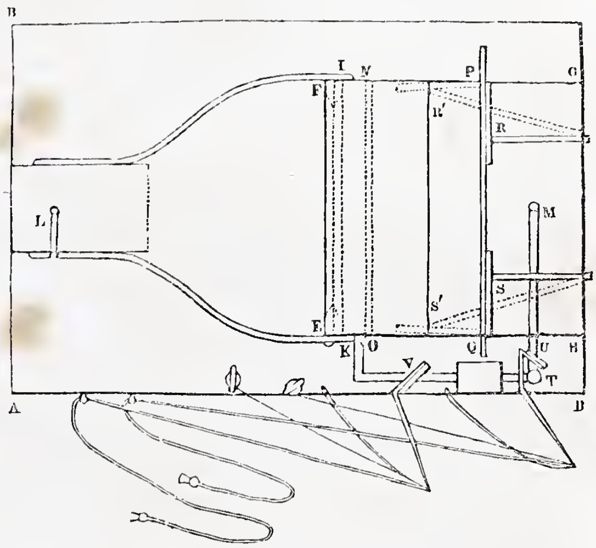



Fig. 2.




A B C D, a board to which the apparatus is attached. The length of the board is 18 inches, and that of the painted surface exposed 6 inches,—but the larger the more striking.

E F G H, a box for receiving the pictures in front at E F.

J K, opening in the side of the box, by which the pictures are introduced successively into a groove in front, behind a border of black velvet, to absorb stray rays from the front light.

L, front light, compact and bright, in a lantern constructed to direct and confine it to the pictures. If the flame be flat and have not a reflector or a lens, its edge may front the pictures. A simple swallow-tail burner, No. 0, gives sufficient light for this scale. The inside of the lantern is done with black japan, flat; and the sides and bottom, and outside of the bottom, and the supports, so far as necessary, are covered with black velvet.

M, back light. Swallow-tail No. 1 is sufficient for this scale.

A circulation of air is admitted to both flames without allowing the escape of light. Their covers are moveable, and are represented on the plan as removed.

N O, opening for receiving into a groove a slight frame of tissue paper, to be used when found of advantage; particularly when any part of a picture, for example the moon, is made transparent.

P Q, opening through both sides of the box, for receiving into a groove an opaque slider, of a length equal to about double the breadth of the box, properly pierced, to be drawn gradually across, in order to represent passing gleams of sunshine; also for receiving a slider or sliders of tissue paper, painted with various tints in succession, to be drawn gradually across, in order to represent changes of tints, for evening or the like, with the back light, where day is represented by that light, as in fog or snow scenes. The light is not to be allowed to pass over or under those sliders.

When a slider is used, the tissue paper N O is to be removed; and the open space in front of the back light is to be contracted to about a third part of its breadth, by leaves moved forward for the time, as represented by R S on the plan, or otherwise.

A narrow projection immediately before any opening, if necessary, prevents the light within from being seen in front.

The box is white within, to reflect light.

T M, T L, on the plan, tubes for gas (the latter consisting of one of the supports of the lantern, hollow), supplied, when in use, by inserting the nozzle of a flexible tube at T, or otherwise.

U V, stop-cocks moved by levers attached, which are closed by springs and opened by cords extending to the front. The levers have checks adaptable to the variable pressure of the gas; for example, linen threads attached to pins turning in the board, so that either flame, when not required, may be reduced to a blue point. The levers and springs are made to fold back upon the board when not in use.

The arrangement now shortly described is given merely as a specimen. The details of any diorama made upon this principle of construction—for example, the description, number, and position of the lights—will, of course, be adjusted according to the judgment of the maker, and will be modified by the size of the apparatus and other circumstances.

It is an improvement to place across the board in front of the pictures, a parapet covered with black velvet, as high as the bottom of the pictures, and at such distance from them as to allow the stray rays from the front light to fall behind it; and also to cover the whole of the upper surface of the board in front of the parapet with black velvet, removing the check pins to the *side* of the board.

## NATURAL PHILOSOPHY AND CHEMISTRY.

### CHAPTER XIX.

ON THE PRESENT STATE OF VOLTAIC ELECTRICITY AND ELECTRO-MAGNETISM.

PART I.—VOLTAIC ELECTRICITY.—(*Continued.*)

83. THE conducting powers of non-metallic bodies—not in solution—do not appear to have been, as yet, determined with sufficient accuracy to justify numerical expression; but substances are generally arranged in the following order of their conducting powers, the worst conductors, or best insulators being placed first:—

| | |
|---|---|
| Dry air. | Damp organic bodies. |
| Shell lac. | Damp air. |
| Resins. | Water. |
| Oil of turpentine. | Strong acids. |
| Sulphur. | Fused saline bodies. |
| Glass. | Charcoal. |
| Spermaceti. | Metals. |

84. It has been determined by the experiments of Watson, and more recently by those of Professor Wheatstone, that electricity moves through conducting bodies with a greater velocity than light, and therefore not slower than 200,000 miles in a second of time.

85. It appears to be the opinion of some eminent physicists, that those differences of effects of current electricity, which have been designated "quantity" and "intensity," are merely consequences of more or less perfect conduction, by which the restoration of the electric equilibrium is rendered more or less easy. It has been ascertained, by varying the number of alternations in the pile, that, if the circuit be closed by an imperfect conductor, the power of transmission of the quantity of electricity evolved in the pile is universally increased in proportion as the number of pairs is augmented.

86. On observing the effects of tension in a pile whose poles were insulated, it has been found that the centre pair exhibited the same degree of intensity that it possessed when alone; two pairs distinct from the centre pair, a greater degree; three pairs a greater still; and so on to the poles where the intensity reached its maximum. On making the electrodes communicate by distilled water, the electricity appeared to be similarly distributed, but was somewhat more feeble. When acidulated water was employed, decomposition took place, and the electricity of tension was still perceptible in those pairs nearest the poles; but, upon connecting the poles by metallic conductors, no trace of intensity was discoverable in any of the pairs.

87. A strong analogy may be observed between these effects and those of the common electric battery; hence, it has been concluded, that the greatest tension or static intensity of the pile is merely a consequence of the resistances presented to the circulation of the current; that this intensity is at its maximum at the poles; and that the greater or less difference in the electrical condition of those poles, causes a greater or less tendency to the re-establishment of the equilibrium, and therefore more or less increases the power of the current to overcome the obstacles presented by imperfect conductors.

88. Whatever may be the degree of faith in the correctness of the foregoing views of the cause and operation of electricity of tension, one thing is quite clear, that the amount of intensity does not in the least depend upon the size of the plates, but is proportionate to the number of alternations; therefore, although we may increase the quantity of electricity prodigiously, as in the Calorimotor, we fail in obtaining those effects which require a certain degree of intensity as well as quantity. Quantity, alone, will suffice for the evolution of heat, ignition of metals, and volta-plastic effects;—ntensity is requisite for the development of the phenomena of ordinary electricity, such as the display of attractive power, the charging of a Leyden jar, &c.; while both intensity and quantity, accompanied by a continuous current, or rapid electric impulses, are necessary for the transmission of electricity through bodies of inferior conducting power, for the production of chemical decompositions, and various physiological effects, and also, of the more important phenomena of electro-magnetism.

89. The consideration, that there is as great a difference between the effects of electricity in quantity, and of the same electricity when possessed of high intensity, as there is between the force or powers of a pound of water and a pound of steam, will show how futile any attempt must be to produce electricity of every quality from any one voltaic combination; but, unfortunately for the successful application of electricity to the improvement of certain arts, combinations are employed, which are totally unfit, and were never intended by their inventors for such purposes; and, the consequence is, that those combinations fail in their novel applications, and prove a never-ceasing source of expense, trouble, and disappointment.

90. It has been clearly demonstrated, that to whatever extent we may increase the number of alternations of a voltaic circle, the quantity of active electricity does not exceed that evolved in a single cell; and furthermore, that if the conducting fluid of any cell happens to be inferior to that of the others in conducting power—no matter from what cause—the electricity evolved in the circuit is restricted to the amount produced by the weakest alternation.

91. But notwithstanding the existence of inferiority of conducting power in the liquid of any cell in the series, or the employment of liquids of different qualities, and of different conducting powers—assuming the number and quality of the different metallic pairs to be the same—it has been proved, that the intensity of the current is invariable; and this, although the differences of the chemical actions exercised upon both elements of each pair in the series were unequal.

92. It has been already stated, (sect. 87,) upon the authority of M. de la Rive, that the intensity of the pile has relation to the greater or less obstruction which the pile itself opposes to the passage of the current; but, if such be the case, it would be sufficient to render the transit of the current through the series more difficult, in order to augment the tension at the poles. To decide this question, the tension of a series of cylindrical pairs being measured, these pairs were removed into different vessels, so much larger than the first, that the liquid stratum (which was rain water in each case,) between each pair, was nearly six times greater; but although the resistance to the passage of the current was thus much increased, the intensity was found not to be in the least augmented.

93. If the above experiment, and others of a similar nature, be correct, the conclusion should be, that the intensity of a given pile is independent of quantity, and unaffected by augmentation of resistance; but that, for a given number of pairs, it is always the same, no matter whether the plates of these pairs be large or small, or some large and some small; and, furthermore, that the intensity being the same, the decomposing power may, nevertheless, diminish, owing to the diminution of conductibility of the pile.

94. The intensity of the voltaic current may be measured by the chemical, physiological, or physical effects which this current is capable of developing; but if the physical effect exercised by it upon the magnetic needle be adopted as the unity of measurement, it will be found to possess the advantage over all others, of being instantaneously developed, and of being capable of the most exact measurement. The results, however, of this mode are not unconnected with those obtainable by taking for unity the chemical or physiological effects; on the contrary, one so much depends upon the other, that the first may be deduced from the second, and *vice versâ*. Such a connexion between effects which differ so much, apparently, and which, at times, appear quite opposite, is a point of no small importance in the theory of

the pile: it goes far towards explaining what is generally called the intensity of current electricity, as well as why it is, that a pile, which produces powerful physical effects, may be extremely ineffective in the production of chemical or physiological effects, and reciprocally.

95. Adopting this mode of measurement, M. Pouillet has made some important experiments, and drawn some highly valuable conclusions, which it would not be proper to pass over. The voltaic instruments employed by him were the constant piles discovered by M. Becquerel in 1829, in which he employed two metals, and two fluids separated by a diaphragm. The intensities of the currents were measured by two different instruments, one called the *compass of tangents*, the other the *compass of sines;* and for very feeble currents, these compasses had a multiplier instead of a simple circuit.

96. In order to ascertain the different degrees of diminution, which the intensity of a current, developed by a single pair, suffers, when it traverses circuits of different lengths, pieces of wire of copper, platinum, silver, iron, &c., covered with silk, and proceeding each from a similar piece of metal, were drawn out with such care that the diameter of each wire was sensibly the same through the entire of its length; from each piece were cut five smaller ones of different lengths, and with each series the following experiments were made:—The current produced by the voltaic pair was made to traverse the compass directly, and the deviation was observed; it was afterwards made to traverse in succession each of the five wires, the corresponding deviation being carefully noted.

97. Many experiments made with the series described, as well as various others made with wires of different kinds, having led to the same result, Pouillet derived from them the following general law:—"The intensity of the current produced by a single pair, is in an inverse proportion to the real length of the circuit." Some analogous experiments have demonstrated that the resistance of the single pair, or the primitive length of the circuit, is expressed by lengths which are proportional to the section, and to the conductibility of the wire which composes the apparent length of the circuit.

98. Inasmuch as the intensity of the current measured by the apparatus is in an inverse proportion to the real length of the circuit, we may draw this important conclusion, that the current produced by a single elementary pair, is capable of a constant electro-dynamic effect; for the influence that is remarked on the magnetised needle, arises only from a certain fraction of the real length of the circuit. But if that influence be increased tenfold—say the real length of the circuit—this fraction becomes ten times as small, and, at the same time, we obtain only one-tenth of the intensity; it is, therefore, clear, that in the two cases, we should obtain equal degrees of intensity, if it were possible, under similar conditions, to cause the total length of the circuits to act on the needle.

99. This must be considered quite a fundamental principle in theory, inasmuch as it demonstrates that the peculiar agency which constitutes the current, may be assimilated to a quantity of motion which must continue constant whatever may be the extent of the mass through which it is transmitted. Thus, if the two poles of a voltaic pair be connected by a wire of one inch, or by one of one thousand inches, neither more nor less electricity passes in the one case than in the other—the quantity that does pass, remains always constant, and depends altogether for its supply on the combination itself, or upon the electric source, whatever it may be.

100. When two points of a circuit, traversed by any current, are touched by the extremities of a metallic wire, the current must be divided at those points—one portion continuing to pass along the circuit as before, and the other taking the direction of the wire. This second portion may be called "derived current;" that portion which passes between the points of derivation, "partial current;" the undivided current, which passes before and after the points of derivation, may be designated "principal current;" and the current transmitted before any derivation was made, "original current"

101. The following general laws have been deduced from the results of experiments upon the intensities of the derived, partial, and principal current:—

1st, Upon a derivation being made, the intensity of the original current is increased; thus, the principal current is always stronger than the original.

2d, The intensity of the derived current is proportional to the distance of the points of derivation.

3d, At an equal distance, the intensity is in an inverse proportion to the section, and conductibility of that portion of the circuit in which the derivation is made.

4th, The sum of the intensities of the partial and derived currents is always equal to the intensity of the principal current.

102. It has been further shown that the principles demonstrated for one elementary pair, apply with equal force to a pile composed of any number of pairs; and it has also been ascertained, upon placing several elementary pairs pole to pole, and thus forming a pile with great surface, and a single element, and connecting the two positive and two negative poles of two such elementary combinations, whose individual intensities had been previously ascertained, that, in each case, the individual currents of the two elementary combinations join and superpose themselves in some way, without any particular modification. This result is important, for it shows that when a wire is traversed by a current of a certain tension, it is not less fitted for the transmission of another current, even though originating from a source of less intensity, which may be taken to afford fresh proof, that the currents are assimilated to certain quantities of motion, and that it is not requisite to consider electric conductors as a species of tube affording passage to a fluid, and presenting an increased resistance in proportion to their increase of length, so that the fluid diminishes in velocity or quantity, and is forced either to reflow toward its source, or, at all events, to be accumulated in a greater proportion.

103. A general view of the experiments referred to in the preceding sections, leads to the two following laws, which are of singular simplicity:—

1st, An electric source is capable of a constant electro-dynamic effect, whatever may be the length, section, and conductibility of the metallic circuit that its current has to traverse.

2d, When several electric sources are connected, their currents join, or superpose themselves without modification.

104. The results of experiments, already very numerous, appear to warrant the conclusion, that an electric source is capable of developing a constant quantity of heat; and that it is possible to calculate by quantities of heat, or of ice melted, the quantities of electricity evolved by voltaic combinations, or other electric sources.

# ANATOMY AND PHYSIOLOGY.

## CHAPTER XVI.

### LIEBIG'S THEORY OF RESPIRATION.

In the article on "the circulation," it was explained, that in the higher classes of animals, the blood was sent through lungs, so as to be exposed to the air, in the intervals between the times in which it was circulated over the body. It was also shown how the heart, and arteries, and veins were modified, in various ways, in order to bring the blood conveniently in contact with the atmosphere. In the last article (p. 551) the quantity of air used was stated; and it was pointed out, of how much importance it is, in building halls or dormitories, to calculate their size, so that their cubic contents may correspond with the respiratory necessities of those who are to occupy them.

It has been ascertained by chemical calculation, founded on careful experiments, that nearly eleven ounces of charcoal are expelled from the lungs in the four-and-twenty hours; so that, in this respect, the windpipe may, not inaptly, be compared to a chimney. We shall see, immediately, that this comparison holds good in another point of view, for the lungs, seen in this light, are extremely like a couple of furnaces. It was long supposed, that the purifying of the blood, by getting quit of its carbon, was all that was necessary—that this was the *end* of the function of respiration. *Now*, on the other hand, there are strong grounds for thinking that this getting quit of the carbon is but a *means* toward an end—that the carbon in combining with the oxygen of the air, is actually *burned*, and that this combustion is the cause of animal heat. It has long been known that heat was in some way the result of breathing, but to explain exactly how, was the difficulty. It has been left, for a chemist of our own day, to set this subject clearly before us—as clearly, perhaps, as it can possibly be. Liebig, the professor of chemistry at Giessen, in Germany, lately published a most admirable book, which has been clothed in an English dress by Dr. Gregory of Aberdeen, who was well known in Glasgow before his removal thither some years ago. The book is entitled, "Organic Chemistry, applied to Physiology and Pathology." A correct abstract of the doctrines of the distinguished author ought to be acceptable in this place, although the writer of these papers cannot, of course, pledge himself for their accuracy in a philosophical point of view.

"Hitherto," says Professor Liebig, "in attempting to investigate the theory of those *vital motions*, which we call the *actions* going on in the intimate structure of animal bodies, only one condition was possessed—namely, a knowledge of the apparatus. The exact nature of the substance of the organs themselves—the changes which they produce upon the food—its transformation into the substance of organs—and afterwards, its transformation again into lifeless or inorganic compounds—also, the share which the atmosphere has in aiding these changes—all these foundations for future conclusions were awanting."

All the parts of the animal frame are formed out of a peculiar fluid, which circulates through every cell of every organ. All the parts consisted originally of blood, or, at least, had been made of materials which were brought to the growing organs by means of this fluid. Experience further shows us, that at every moment there is a change taking place; that a part of the structure is losing its life, becoming transformed into unorganized matter, and requiring to be renewed, and to have its place supplied. Besides, every motion, every manifestation of power, must be the result of a transformation of structure or of substance. In order to keep up the phenomena of *life*, then, there must be *nourishment*. Some part of this is wanted for the increase of the mass, some part is needed for repairing loss, and some part is expended in producing force.

If, then, the *first* condition, necessary for the maintenance of life, be a due supply of nourishment, the *second*, of no less importance, is the *absorption of oxygen from the atmosphere*. Viewed as an object of scientific research, animal life exhibits itself in a series of phenomena, consisting of the *changes* which the food and the oxygen which have been taken in undergo *in the body*, under the influence of *life*, or what has been called *vital force*. We say, under the influence of life, because, though all the parts remain the same, these changes do not go on in the dead body.

During life, there are constantly two changes going on; there is new matter moving in, and *passing to* a state of rest; and there is old matter, which *has been* at rest, passing into a state of motion; in two words, there are the processes of *addition* and *decomposition*. In vegetables, we do not see this double change, but only the first; we see new matter passing into a state of rest, and adding to their size and growth, but we see no waste. In animals, there is both growth and waste.

The matter taken in consists of food and oxygen. Food is taken at certain times; oxygen is taken continually, without ceasing. Yet, accurate experiments have shown, that a man, supplied with a sufficiency of food, and breathing regularly, neither becomes heavier nor lighter in the twenty-four hours, and yet the quantity of food and of oxygen taken in must have been very considerable. In a year, a man takes in 746 lbs. of oxygen, yet his weight remains the same, or has varied but a few pounds. What, then, has become of it? The question can be answered satisfactorily,—no part of it has remained; it has all been given out again, in the form of compounds, with carbon and hydrogen. The carbon and hydrogen of certain parts of the body have entered into combination with the oxygen of the atmosphere, through the lungs and skin, and have passed off under the forms of carbonic acid gas, and the vapour of water. At every moment, at every expiration, certain quantities of these elements separate from the body, having combined, within it, with the oxygen of the atmosphere.

Suppose that a man has 24 lbs. of blood within his body, (a very small quantity, but it will serve for the basis of a calculation,) from its known chemical composition, in order to convert the whole of its carbon and hydrogen into carbonic acid and water, 64,103 grains of oxygen will be required, which quantity will be taken in at the usual rate of breathing in four days and five hours.

It is quite plain, that whether the air combine directly with the blood, or with other parts of the body, which it carries away, so as to form carbonic acid—the body of a man, which takes in daily 32½ ounces of oxygen, must daily receive as much carbon and hydrogen, from without, as will supply the blood anew with these elements, to supply the place of the old quantity which has been parted with, in order to combine with the air. Further, since no part of the oxygen taken in by breathing is again given off, except as a compound of carbon or hydrogen; and since the carbon and hydrogen given off are replaced by carbon and hydrogen in the food, it is clear that the amount of nourishment required by an animal which breathes air must be directly proportionate to the oxygen which is taken into the system.

Two animals, which, in equal times, take up by means of the lungs and skin, unequal quantities of oxygen, consume unequal quantities of nourishment. Then, the quantity of oxygen taken up depends on the *number* of the respirations; hence, the quantity of nourishment will vary according to the number and force of the respirations. A child, in whom the respiratory function is very active, requires food oftener than an adult, and bears hunger less easily. A bird, whose consumption of oxygen is so great that its blood is three or four degrees hotter than a quadruped's, dies on the third day that it passes without food; while a serpent, whose respiration is very sluggish, will live without eating, for three months, or more. Again, the number of respirations is smaller when we are at rest, than when at active employment, so that the quantity of food required will vary on this account also. An excess of food, then, without exercise, and the increased frequency of respiration, and increased consumption of oxygen, which are necessary accompaniments, is bad for the health; and so, also, is the opposite, increase of exercise, or excessive labour, without a sufficient supply of food. In either case, the constitution suffers.

Again, the chemist shows us that air expands by heat, and becomes denser under the influence of cold. The *bulk* of the air used in respiration continues the same, but its *weight* varies. Besides, in summer, the air contains a proportion of watery vapour, in consequence of the evaporation which the heat is occasioning; while in winter it is dry, in so far as this source of moisture is concerned. Hence, the space which in summer was occupied by vapour, is in winter occupied by air itself; and that air, from its density, contains more oxygen.

It is clear, then, that since in winter, we draw in more *oxygen*, during respiration, than in summer, we must also send out more. But we send it out as *carbonic acid*, in consequence of the combination with it of the *carbon* which has

been brought to the lungs in the venous blood, after having been collected in the course of the circulation. More carbon then is given off in winter than in summer; that is to say, there is more *waste* constantly going on. Henee arises the necessity for more food in winter than in summer—a feeling of which every one is conscious, though he does not know its cause. In warm climates, for the same reason, the food taken in is less nourishing in its quality, as well as less in quantity—the people live on fruits and grain, while, in the far north, they luxuriate on fat baeon and train oil. It is no difficult matter to be moderate in warm climates—want of food can be borne for a long time under the equator; but cold and hunger united, soon exhaust the strongest body.

Another very interesting branch of this subject next comes before us, namely, that the mutual action of the food and oxygen in the body, is the *source of animal heat.*

All living creatures, depending for existence on the breathing of oxygen, have a source of heat within themselves, independent of surrounding objects. This statement holds true of all animals, and its application extends to the springing of seeds, the flowering of plants, and the ripening of fruits. Only those parts to which the oxygen goes, possess heat. Those parts which have no circulation, as hair, wool, and feathers, have no heat in themselves; they aid in keeping a creature warm, because they neither radiate nor conduct heat. The temperature of animals, therefore, is the result of the combination of carbon with oxygen. This combination, chemists well know, *cannot* take place *without heat;* and whether it be evolved so rapidly or so slowly, as to produce a high or a low temperature, still, the absolute quantity of heat is the same.

Every one, who has attended the most popular chemical lecture, has seen a bit of charcoal burnt with great splendour in a jar of oxygen. Now, the carbon of the food, converted into carbonic acid in the body, gives out as much heat as if it had been burnt. In pure oxygen, the heat is intense, because the combustion is rapid; in common air it is less intense, because slower; within the body, it is more gradual still.

From all that has been said, it must be plain, that the heat of the body will be greater or less, according to the greater or less quantity of oxygen used in respiration. The more frequent the respirations, the greater will be the heat. An infant, who breathes thirty times in the minute, maintains a temperature of 102°, while an adult, who breathes eighteen times, will show a heat of only 98°. Birds maintain a temperature of 104° or 105°; quadrupeds from 98° to 100°; and even fishes and amphibia, are 2° or 3° warmer than the water in which they live. All animals, therefore, are strictly *warm-blooded, i. e.,* warmer than the medium in which they live, though only so warm as to deserve the name, in those who breath by means of lungs. The most trustworthy observations on the temperature of man and the lower animals, show that it remains the same in all climates, being regulated by several different circumstances.—(See Vol. I. p. 202.)

The animal body is a heated mass, bearing the same relation to the surrounding objects, as any other heated mass, which receives heat, or loses heat, from the other bodies round it. Its rapidity of cooling will vary as the external temperature varies; yet the lost heat is made up, and the temperature is kept equable.

It is evident, then, that the heat lost by cooling is supplied by the mutual action of the elements of the food and the inspired oxygen, which combine together. The animal body is a furnace, of which the food is the fuel. It matters not what forms the food assumes, nor what changes it undergoes within the body—the *last* change is always the same; carbon is converted into carbonic acid, and hydrogen into water, each by the addition of oxygen; while the unburned carbon, and the nitrogen, whether from the unused food, or from the old parts of the body which have been absorbed, are expelled as urine and perspiration, or as solid excrement. Of course, in order to keep the furnace at a constant temperature, we must vary the supply of fuel according to the temperature of the surrounding air, as that regulates the supply of oxygen, by altering its density.

From what has been said, it must be plain, that in winter, when we take active exercise in the cold air, and the amount of oxygen which is inspired, increases, our need for food containing carbon and hydrogen increases in the same ratio; and it is a wise provision of our Creator, that, by gratifying the appetite which has been thus excited, we obtain the most sufficient protection against the most piercing cold. A starving man is soon frozen, as we should expect from this rule, and the beasts of prey in the arctic regions greatly exceed in voracity those of the torrid zone.

In the temperate and frigid zones, the denser air which is respired consumes the body so much faster, that it urges men to labour, to furnish the means of subsistence; while in hot climates, the waste being much less, the necessity of labouring for food is much less urgent. Hence, the natives are reckoned lazy; and those, whose state of slavery deprives them of the power to choose, are compelled by the lash to labour for others whose station in life enables them to comply with the requirement of the climate by living at ease. Our clothing, in this point of view, is merely an equivalent for food. The more warmly we are clothed, the less urgent is the need for food, because the loss of heat by the cooling of the surface, and the necessity for supplying it again by food, are lessened too. If we ran about naked, like savages, hunting and fishing, we should be able, during the cold of winter, to eat, like the Samoiedes, eight or ten pounds of flesh at a sitting, and finish with a dessert consisting of a dozen of tallow candles! The spirits and the train oil which these northern savages swallow in such profusion, consist of combustibles, carbon and hydrogen, and only suffice to keep up the equilibrium between the external temperature, and that of their own bodies.

Let us now look at this subject in relation to health. The Italian cannot take more carbon and hydrogen in his food than he expires under the form of carbonic acid and water; and the Laplander cannot expire more carbonic acid and water than he takes in as food, unless in starvation, or while labouring under disease. The Englishman in Jamaica regrets the disappearance of his appetite, which had previously been to him a source of constantly recurring enjoyment, and he succeeds, by means of pepper and other stimulants, in getting himself to swallow as much food as he was accustomed to do at home. But *the whole of the carbon is not consumed,* the oppressive heat prevents him from increasing the number of respirations by active exercise, and so proportioning the waste to the amount of food taken; the carbon, therefore, accumulates in the system, and disease is the inevitable consequence.

On the other hand, England sends her sick, whose deranged digestive organs have lost the power of bringing the food into a fit state for combining with oxygen, and therefore are, *in their own persons,* ready to be consumed by it, to southern regions, where, from the heat, the amount of oxygen inspired is diminished in so great a proportion; and an obvious improvement in health is the result. The weak organs of digestion have power enough to digest food enough to combine with the smaller quantity of heated oxygen which is inspired; while, in a colder climate, this necessary amount of digestion being impossible, *the organs of respiration, the lungs themselves,* would have become the fuel to the flame. In our own climate, bilious diseases, or those from excess of carbon, are prevalent in summer, while pulmonary diseases, or those from excess of oxygen, prevail in winter.

The cooling of the body, it has been already explained, increases the amount of food necessary, and so is an important agent on the health of the digestive organs. Mere exposure to the air, even without exercise, in a carriage or a boat, by increasing radiation and vaporization from the surface, increases the loss of heat, and compels us to eat more than usual. The same is true of those who take large draughts of cold water, which is given off again in perspiration, or urine, at the temperature of the body, 98°. This process increases

the appetite, to restore the carbon, and renders exercise necessary to quicken the breathing, so that oxygen may be supplied, in order to restore by combustion, the heat which had been carried off by the vaporization of the cold water. For this reason, long continued speaking, the crying of infants, and the dryness of the air, all exert a decided influence on the quantity of food taken.

The effect of the process of respiration is clearly seen, if we watch the state of a man or other animal, totally deprived of food. The first effect of starvation is the complete disappearance of the fat; and this fat cannot be traced into either the urine or the excrement. Its carbon and hydrogen have been given off by the lungs, in combination with oxygen, and have obviously served to support respiration. In the case of a starving man, 32½ ounces of oxygen enter his body daily by the lungs, and pass out again, in combination with carbon and hydrogen, of which there will be about eleven ounces of the former. An individual, who was unable to swallow, lost 100 lbs. of his weight in a month; and a fat pig, which was overwhelmed by a slip of earth, and was dug out after passing 160 days without food, had lost 120 lbs. The way in which the hybernating animals waste during the winter, and the periodical fattening of many animals in the autumn, and their getting leaner during the winter, are additional proof that the oxygen consumes whatsoever is capable of entering into combination with it. As starvation goes on, the fat having been exhausted, the muscles shrink, and the brain becomes partially absorbed; hence delirium and ravings occur before death closes the scene. In all chronic or long-continued diseases, death is at length produced in the same way, chiefly from the wasting occasioned by the chemical influence of the atmosphere.

## GEOLOGY.

### CHAPTER XIV.

#### FOSSIL PLANTS OF THE COAL FORMATION.

When led to admit the vegetable origin of coal, we naturally direct our attention to the character of the plants from which it was produced; and here a field of inquiry opens on our view, replete with interest, whether we contemplate it with the eye of the botanist, or the scrutiny of the philosopher. In the fossil plants of the carboniferous rocks, we find genera, and even families which have been long lost in the scale of vegetable creation, but so connected with the existing order of Nature, as to fill up the links which seemed wanting to complete the harmony of creation; and in others we are able to trace analogies of structure and form, that forcibly convey to our minds the impression, that from the time our infant planet began to be adorned with the beauties of the vegetable kingdom—though its floral riches, the garniture of blossom, or the luxury of fruit, were not conspicuously developed, —yet the plants of that most remote epoch must have displayed a symmetry of structure, and gorgeousness of appearance, not surpassed, if even equalled, by the tropical forests of the present day.

The generality of the stems of plants found in the coal formation are commonly so much compressed, as to warrant the conclusion that they were hollow or succulent. As already noticed, they occur in the sandstones, clays, shales, and half-formed coal. The best impressions are found in the shales, or slaty clays; on the surface of which the most delicate markings are preserved of the nerves of the leaves, and the dottings and striations of the stems. In many instances, the bark is converted into coal; while the central portion of the stem consists of the same material as the bed in which the plants occur. In other instances, instead of the sandstone or shale which forms the matrix, the mass is converted into carbonate of iron, sometimes crystalline, or a calcareo-silicious compound.

The roofs of some of the coal-beds exhibit great beauty of appearance, and a vast profusion of plants. The most remarkable that has come under our personal observation is that of the splint-coal at Monkland Iron Works, near Airdrie. It answers very much to the following magnificent description of a similar deposit, by the Rev. Dr. Buckland:—"The finest example," says he, "I ever witnessed, is that of the coal mines of Bohemia. The most elaborate imitations of living foliage upon the painted ceilings of Italian palaces, bear no comparison with the beauteous profusion of external vegetable forms with which the galleries of these instructive mines are overhung. The roof is covered with a canopy of gorgeous tapestry, enriched with festoons of most graceful foliage, hung in wild irregular profusion over every portion of its surface. The effect is heightened by the contrast of the black colour of these vegetables with the light ground of the rock to which they are attached. The spectator feels himself transported, as if by enchantment, into the forests of another world: he beholds trees of forms and characters now unknown upon the surface of the earth, presented to his senses almost in the beauty and vigour of their primeval life; their scaly stems and bending branches, with their delicate apparatus of foliage, all spread before him, little impaired by the lapse of countless ages, and bearing faithful records of extinct systems of vegetation, which began and terminated in times of which these relics are the infallible historians."

The plants, which occur in the manner so beautifully described by the Doctor, are generally not in direct contact with the coal-bed, but at a little distance above it. The fern fronds and other leaves are separated from their stems, and frequently lie in the most confused manner, intermingled with long stems of stigmaria, denuded of their leaves—gigantic calamites—and the long sedge-like leaves of the flabellaria, a plant allied to the gramineæ, or the palms. As far as our observation has gone, stems of Sigillaria, and Lepidodendra, are rare in such situations. The leaves of most common occurrence are those of ferns. Fruits, apparently those of palm trees, sometimes occur. It is perhaps worthy of remark, that the shales in which commingled collections of fossil vegetables are met with, generally contain perfect casts of bivalved shells (unios ?), and the remains of fishes—a circumstance which tends to show that, whether the plants constituting the coal-beds grew on the spot or not, the vegetable remains imbedded in the superincumbent shales were drifted from a distance.

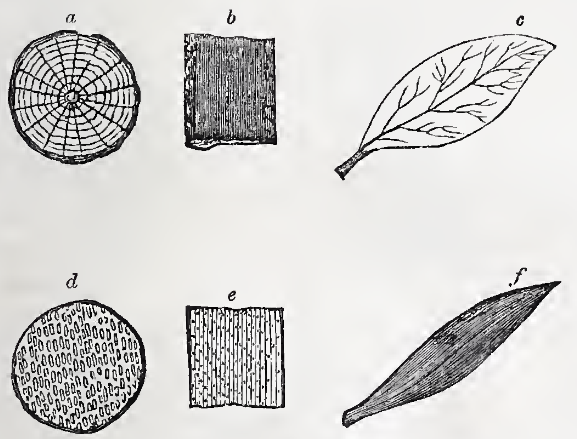
A very ingenious plan has lately been devised for ascertaining the true character of fossil plants, by cutting the coal, or other substances into which they have been converted, into thin transparent slices. Geologists had hitherto only attempted to classify fossil plants by the peculiarities of their external appearance. This, however, was very unsatisfactory, because the external markings are frequently defaced, and the bark converted into coal, in which little or nothing of the outward character of the plant is preserved. By cutting the specimens, however, into thin slices, and subjecting these to the microscope, or even, when sufficiently transparent, to the naked eye, we are able to trace the minute cells and vessels of the original vegetable texture, with an accuracy and distinctness equal to that by which we become acquainted with the structure of living species. It was by means of this kind that Mr Nicol of Edinburgh was enabled to ascertain the coniferous character of the celebrated trees found in Craigleith quarry, near Edinburgh, about twenty years ago; and to determine them to have belonged, not to the common fir, but to the Araucaria, a genius of pine now only found in Norfolk Island, South America, and New Holland.

In order to accommodate such of our readers as may not be acquainted with the physiology of the vegetable kingdom, it may be useful to notice briefly a few of the leading phenomena connected therewith, before entering upon a description of the coal plants.

The matter of which the various parts of vegetables are composed consists of two substances, denominated vascular and cellular tissue. Those plants which, like the fungi or mushroom tribe, consist exclusively of cellular tissue, are

called Cellulares; while those which are constituted of both cellular and vascular tissue, as all flowering plants are, are named Vasculares. These form the two grand divisions of the vegetable kingdom. Vascular structure consists of small fibres or tubes, like hairs, which run from the root, in straight or spiral directions, to the remotest branches and leaves, to all parts of which they convey the sap or nutriment. Cellular tissue consists of small vesicles or cells, of nearly equal size, primarily globular; but, owing to compression, they commonly assume a honeycomb-like appearance. The cells are divided by a thin pellicle or skin, like thin paper. So minute are they, that ten millions of vesicles are computed to be contained in a fungus three or four inches broad, and half-an-inch thick.

Vasculares are divided into two great classes, viz., Dicotyledons; that is, plants which have two cotyledons, or seed-leaves; and Monocotyledons, plants which have only one cotyledon. Dicotyledonous plants are also termed Exogens, their wood being increased annually by additions to the outside. The Monocotyledons are called Indogenes, on account of their not increasing externally by annual layers, but by internal accretion. Besides these very striking characteristics as regards the growth, the structure and appearance of the leaves are quite different. In the leaves of the Dicotyledons, or Exogens, the petiole, or leaf-stalk, is extended directly through the web; and, as it proceeds, sends off branches towards the margin on both sides: whereas, in a leaf of a monocotyledonous plant, there is no costa or mid-rib, the petiole being divided into several parts, which run in nearly parallel lines from the base to the apex of the leaf. Examples of the structures of dicotyledonous and monocotyledonous plants may be seen in the leaves of the common hawthorn or beech, and in common grass, or in any liliaceous plant. The concentric rings occasioned by the annual external accretions of Dicotyledons are to be seen in the horizontal cutting of the common fir, or any other forest tree; while the Monocotyledon structure may be observed in the palms, the stems of lilies, or grasses.




*a*, Horizontal section of a Dicotyledonous stem. *b*, Vertical of ditto. *c*, Leaf of a Dicotyledonous plant. *d*, Horizontal section of a Monocotyledonous stem. *e*, Vertical section of ditto. *f*, Leaf of a Monocotyledonous plant.

The Cellulares, the second grand division of the vegetable kingdom, as already mentioned, are composed, with few exceptions, of cellular tissue exclusively. They yield no flowers, having neither pistils, stamens, nor corolla; but are reproduced by small sporules, discharged from their conceptacles, and rise from the earth without Cotyledons, or seed-leaves. Hence they are called Acotyledons, or Acotyledoneæ. They are also termed Acrogens, from their stems increasing materially during the period of growth, not in thickness, but in length. They are also designated Cryptogamia; from κρυπτὸς, hidden, and γάμος, marriage—*gamia* being the term used in the Linnæan system of botany to denominate the relation of the pistils and stamens of flowers; and these being absent in the Cellulares, they are, in the language of the Linnæan system, called Cryptogamous plants. The following families or orders belong to this class:—

1st, Foliaceæ, or leaved varieties, including the Filices, or Ferns; the Equisetaceæ, or Horsetails; the floating Marsiliaceæ; the Musci, or Mosses; and the Hepaticas, or Liverworts.

2d, The Aphylliæ, or leafless varieties, including the Algæ, or sea-weeds; the parasitic Lichens; and the Fungi, or mushroom tribe.

These distinctions in the natural classification of plants being understood, will better enable the reader to understand the deductions to which we are led by an examination of the fossil Flora of the carboniferous system, the most remarkable plants of which we shall now attempt to describe, commencing with the

*Equisetaceæ.*—The equiseta, or horsetail plants of the present day, vegetate chiefly in swamps and ditches. They are found in all latitudes, from Lapland to the Equator. They are of most frequent occurrence in temperate regions, but attain the greatest magnitude in the humid and marshy districts of the torrid zone. The name frog-pipe is given to them in England; and puddock-pipe, its equivalent, is that by which they are commonly known in Scotland, from the situations in which they grow being the haunt of the frog. They consist of hollow upright jointed stems, striated longitudinally with a sheath at the joints, from which proceeds a whorl of linear leaves, bearing spikes of fructification at the vertices. The order contains only one genus, including several species.

Brongniart has divided what he calls the fossil equiseta into two genera, one of which he considers identical with the living Equisetum; but the other, which he designates Calamites, from *calamus*, a reed, differs so much from it, that there appears sufficient reason to question the relation of the order to the Equiseta altogether, and to believe that the Calamites belong to a race of plants entirely extinct. The possession of true bark, which the Calamites appear to have, has induced Lindlay and Hutton to consider them as Dicotyledons; bark, in the existing order of nature, belonging exclusively to that division of the vegetable kingdom.

The Calamites are characterized by large or small simple articulated cylindrical stems, striated longitudinally. Some of them have been found 18 feet in length, and 14 inches in diameter. The greater portion, however, vary from 1 to 3 inches in width.

Calamites approximatus.

Brongniart has enumerated twelve species of Calamites, and two of Equiseta, as belonging to the carboniferous formation. The extremely large size of these plants, when compared with living equiseta, which seldom exceed three or four feet in length, and half an inch in diameter, has been appealed to by certain geologists as evidence of an extremely high temperature at the time of their growth; but as the evidence of their identity with the Equiseta is without foundation, the inference, in as far as their extreme size is concerned, entirely fails. Judging, however, from the nature of the ferns and other plants with which they are almost always found associated, there is every probability of their having chosen similar habitats, namely swampy marshes, like the recent Equisetaceæ.

*Filices or Ferns.*—The perfect state in which the leaves and fronds of ferns are found in the shales of the coal formation, enable us to trace the most remarkable coincidence between the fossil and existing genera. Living ferns are classed from the arrangement of the organs of fructification on the leaves; but as these rarely occur in the fossil state, the distribution of the nerves and the forms of the leaves form the basis of Brongniart's classification.

There appears no decided reason for believing that ferns contributed to any great extent in the formation of coal: yet the beauty of their fronds, their vast antiquity, and the light they shed upon the condition of the earth during the coal era, invest them with an interest of no common kind. In both the living and fossil state they form the most numerous of vascular acotyledonous plants. They are distinguished from all other vegetables by the peculiar division and distribution of the veins of the leaves, and in arborescent species by their cylindrical stems without branches, and by the regular disposition of the scars upon the stem at the point, from which the petioles or leaf-stalks have fallen off. The following figures of some of the genera of most common occurrence in the coal formation will convey a better and more distinct idea of the nature of these interesting relics of a vast antiquity, than a written description can do:—

*a*, Sphenopteris Artemisæfolia. *b*, Pecopteris Adantoides. *c*, Cyclopteri Beanii. *d*, Neuropteris gigantea. *e*, Odontopteris obtusa. *f*, Glassopteri Phillipsii. *g*, Longopteris Briccii.

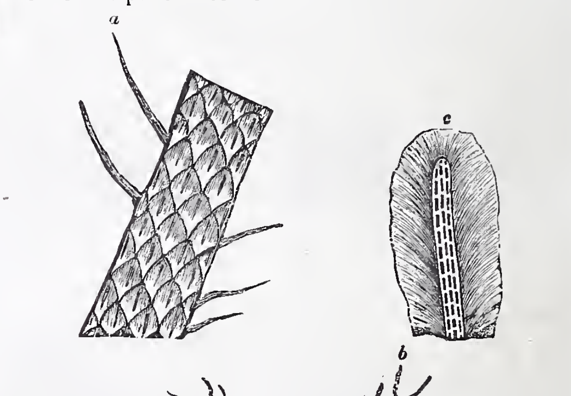
The total number of living species of ferns is about 1500, 1200 of which belong to tropical climates. The temperate and frigid zone of the northern hemisphere yield 144 species, those belonging to the south temperate zone, are 140 species.

"If we compare," says Dr Buckland, "the amount of ferns with the united members of other tribes of plants, we may form some idea of the relative importance of this family in the vegetation of the district or period to which we apply such comparison. Thus, in the entire number of known species of plants now existing on the globe, we have 1500 ferns and 45,000 phanerogameæ—flowering plants—being in the proportion of 1 to 30. In Europe this proportion varies from 1 in 35 to 1 in 80, and may average 1 in 60. Between the tropics, Humboldt estimates the number in equinoctial America at 1 in 36; and Mr Brown gives 1 in 12 as the proportion of those parts of intertropical continents which are most favourable to ferns." Mr Brown states, that the circumstances most favourable to their growth are humidity, shade, and heat, conditions most frequently met with in small islands considerably elevated above the level of the sea, where the air is much charged with humidity. Thus, in Jamaica, the ferns are as 1 to 10 to the flowering plants; in New Zealand, as 1 to 6; in Taiti, as 1 to 4; in Norfolk Island, as 1 to 3; in St Helena, as 1 to 2; and, in the extra-tropical island, Tristran, as 2 to 3.

These facts are important, as illustrative of the conditions of the districts in which coal is now found, at the period of its formation. The plants discovered in the carboniferous rocks consist of about 300 species,—120 of which belong to the fern family. It has thence been inferred that conditions, such as are exhibited in the tropical countries to which we have alluded as favourable to the growth of such a vegetation, prevailed in the latitudes where coal is now found.

Stems of arborescent ferns are occasionally met with in coal strata, but they are very rare. Such plants are chiefly tropical, though one species has been found growing in Zealand, and others in the temperate latitudes of the southern hemisphere. In rocks of secondary formation, the relative number of ferns is much decreased, whereas, in the tertiary beds, they appear, according to Brongniart, to bear nearly the same proportion as they do to flowering plants at the present day in temperate latitudes.

*Lepidodendron.*—Plants of this family are very abundant in the coal formation. They derive their name from the scaly-like appearance exhibited on the surface of their stems —λεπὶς, a scale, and δένδρον, a tree—the markings of which somewhat resemble the reticulations observable on the cone of the fir or the stems of larch. The same kind of reticulated appearance is present on the stems of the plants called Lycopodiums, or club mosses,—low creepers found on heaths and barren hilly places, and to which the gigantic Lepidodendra are supposed to have been nearly allied, as holding an intermediate position between them and the coniferæ or firs.



*a*, Lepidodendron Steinbergii. *b*, Lepidodendron gracile. *c*, Lepidostrobus variabilis.

The leaves of the Lycopodiaceæ are simple, and arranged in spiral lines round the stem, which is marked by lanceate or rhomboidal scars. The same arrangement takes place in the Lepidodendron, the branches of which are forked, in

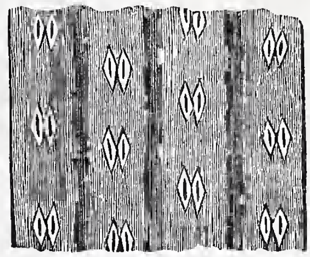
which respect they differ from the firs. From the middle of each scar there proceeds a simple lanceate leaf. The stems are often of a great size, measuring 40 or 50 feet or more in length, and sometimes four feet in diameter. In their internal structure they have been discovered to be intermediate between the Lycopodiums and the firs. "To botanists," says Messrs Lindlay and Hutton, "this discovery is of very high interest, as it proves those systematists right, who contend for the possibility of certain chasms now existing between the gradation of organization being caused by the extinction of genera or even of whole orders, the existence of which was necessary to complete the harmony which it is believed originally existed in the structure of the vegetable kingdoms. By means of the Lepidodendron, a better passage is established from flowerless to flowering plants than either by equiseta or cycas, or any other genus."

Cones of different sizes and ages are frequently met with in the coal formation, to which the name Lepidostrobus has been applied. Brongniart considers them as belonging to the Lepidodendron, but of this there is no certainty, the cones never having been found in connexion with that or any other plant.

Lepidodendra, says a writer in the *Penny Cyclopædia*, are usually quoted as an instance of ancient species belonging to the same genus as modern plants of very humble stature, (for existing Lycopodia, although they acquire sometimes the length of two or four feet, are always more like mosses than trees,) having arrived at gigantic dimensions in the remote ages when coal was deposited. But it is highly probable that the notion is altogether unfounded; for, in the first place, there is no certainty whatever that the most gigantic Lepidodendra were not fir trees analogous to Araucaria, a conjecture that is rendered the more probable by Mr Nicol's discovery that some of the specimens of fossil coniferous wood are nearly identical with wood of that genus. Now, the Norfolk Island pine, Araucaria excelsa, is one of the largest of known trees. In the second place, the Lepidodendron Harcourtii, at the least, is not a Lycopodeaceous plant at all, but of an extinct genus intermediate in organization between coniferæ (firs) and Lycopodeaceæ, connecting gymnosperms (naked seed plants) and acrogens (flowerless plants) more directly and satisfactorily than any known plant. It is impossible to say how many other species of Lepidodendra may be like L. Harcourtii, and it is obvious, being an extinct form, we have no more reason to be surprised at its being larger than the genus Lycopodium now is, than we should have at finding a fern tree like Alosophila Brunoniana, whose stem is between forty and fifty feet high, in the same natural order with the common polypodium of our hedges.

*Sigillaria*.—The Sigillaria were plants with perpendicularly fluted stems, and peculiarly varied symmetrical workings or scars, on the line of the ridges between the flutings, to which it is supposed the leaves or fronds of the plant were attached; but as these have never been found in connexion with the stems, we are in entire ignorance as to their nature, and able in consequence to form but a vague conjecture as to the true habits of this extinct form of vegetation. The stems have had a distinct bark, and we have seen specimens in which there were several vertical bundles of spiral vessels throughout the stem. Brongniart considers the Sigillaria as a variety of arborescent ferns, but Lindlay and Hutton regarded them as having been more allied to the Euphorbias or Cactuses. "There can be no doubt," says the latter, "that as far as external characters go, Sigillaria approached more nearly to the Euphorbiæ and Cacteæ, than to any other plant now known, particularly in its soft texture, in its deeply-channelled stems, and, what is of more consequence, in its scars, placed in perpendicular rows between its furrows. It is also well known that both these modern tribes, particularly the latter, arrive even at great stature; further, it is extremely probable, nay, almost certain, that Sigillaria was a dicotyledonous plant; for no others at the present day have a true separable bark. Nevertheless, in the total absence of the leaves and flowers of these ancient trees, we think it better to place the genus among other species, the affinity of which is doubtful."

Sigillaria are frequently found from two to three feet or more in diameter, and sometimes in a vertical position in the strata. Some of these trees probably attained a height of from sixty to seventy feet. When they occur in sandstone, the bark is usually converted into coal, and the stems are not compressed as they generally are when found in shale, or imperfectly formed coal, in which they are almost always present.



Sigillaria Reniformis.

Sigillaria is one of the most abundant of the true coal plants, and contributed probably more than any other to the formation of that important mineral. Forty-two species are enumerated by Brongniart, as occurring in the carboniferous system.

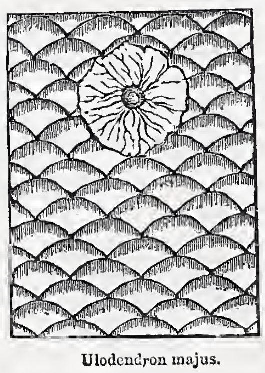
To the same family belong other four genera figured by Lindlay and Hutton, all of which have their scars arranged in vertical rows, a disposition met with among a very few existing plants of a succulent nature, whereas in the coal formation, out of about eighty species of trees, forty have their scars so arranged. The remainder are Lepidodendra and extinct pines.

The Sigillarian genera are:—

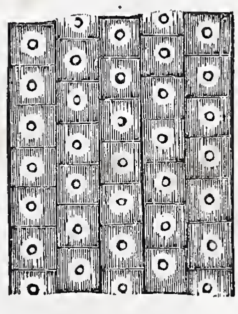
1st, Sigillaria, having the stem furrowed, and the scars of the leaves smaller and much narrower than the ridges of the stem between which they are situated.

2d, Favularia. These have the stems also furrowed, with the scars of the leaves small and square, and as broad as the ridges of the stem.

3d, Ulodendron has the stem not furrowed, but covered with scales closely imbricated over each other in the same manner as the cones of a pine, and ornamented with round scars on which it is conjectured mosses of inflorescence or cones grew.



Ulodendron majus.



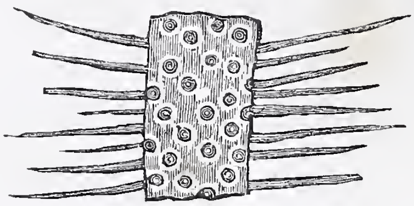
Favularia tessellata.

4th, Megaphyton has the stem not furrowed but dotted; the scars of the leaves are large, and of a horse-shoe shape. They are much narrower than the ridges.

5th, Bothrodendron has the stem not furrowed, but covered with dots and scars of cones of an obliquely oval shape.

*Stigmaria*.—The Stigmaria is by far the most common of the fossil plants found in the strata of the carboniferous rocks, and perhaps the most extraordinary. There is every reason to believe that it was an aquatic plant, floating on the water, or growing in mud at the bottom, for evidence of which we beg to refer to some facts stated respecting it in our last article, when treating of the origin of coal. We are indebted to Messrs Lindlay and Hutton for a knowledge of the real character of this extraordinary plant. Its centre consisted

of a dome-shaped trunk or stem three or four feet in diameter, the substance of which was probably yielding and fleshy;



Stigmaria Ficoides.

but its surfaces were slightly corrugated and covered with indistinct circular spots. From the margin of this dome, there proceeded many horizontal branches, varying in number from nine to fifteen. Some of these branches became forked at unequal distances from the dome, the extent of which, when perfect and outstretched, was probably from twenty to thirty feet. The surface of each branch is covered with spirally disposed tubercles resembling the papillæ at the base of the spines of the Echinus; from each of these tubercles there proceeded a cylindrical, and probably a succulent, leaf. These extended several feet from all sides of the branches. The leaves are usually in a compressed state, and are found penetrating in all directions into the sandstones or shales which form the surrounding matrix; they have been traced to the length of three feet, and are said to be much longer. The stem of each branch appears to have been a hollow cylinder, composed exclusively of spiral vessels, and containing a thick pith. The transverse section exhibits a structure somewhat resembling that of the pines, but destitute of concentric circles, and with open spaces, instead of the muriform tissue of medullary rays. These cylindrical branches are usually disposed on one side. Adjacent to this depression, there is found a loose internal eccentric axis, or woody core, surrounded with vascular fasciculi or bundles that communicate with the external tubercles and resemble the external axis within the stems of certain species of Cactus.—(See Dr Buckland's *Bridgewater Treatise.*)

*Asterophyllites* occur very frequently in the coal shales. These possessed slender stems, and had whorled lanceolate leaves, like the modern genus Gallium.

*Sphenophyllum* has much of the same character as Asterophyllites, but the whorled leaves are broad and wedge-shaped, the veins of the leaves are forked like the forms to which it is nearly related.

Asterophyllites foliosa. Sphenophyllum erosum.

These plants, with occasional traces of native fern trees and pines allied to Araucaria, constitute the known Flora of the carboniferous era,—a Flora which, considered attentively, seems to justify the opinion of a higher temperature in these latitudes during the coal era; but that we have direct evidence of the existence of tropical heat may be disputed, as fern trees grow in New Zealand, and on the south side of Van Diemen's Land, where the mean temperature does not exceed 54° Fahr.; and palm trees are mentioned by Humboldt as having been found by certain travellers in 53° south latitude, while the gigantic wax palm flourishes among the snow-clad summits of Jolima, San Juan, and Quindieu, from five to six thousand feet above the level of the sea. The great prevalence of ferns is the chief argument for the existence of tropical heat in the situations where coal is now found during the period of its deposition; but we ought to recollect that in the experiment made by Mr Lindlay on the comparative destructibility of plants when immersed in water, that ferns were the most enduring. Many species, genera, and even families, then flourishing on the surface of the earth, may have entirely disappeared. Still, taking the whole facts into consideration, we are disposed to think that a higher temperature existed than we now enjoy, though not so materially different as some geologists have supposed.

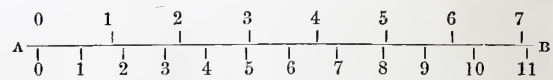
It has been thought by some that the plants of the earlier epochs were not so completely organized as those of a later date, and that Nature has been perfecting her work in the various creations which subsequently took place. Of this theory the history of fossil vegetation affords no evidence whatever. It is true that a greater diversity by far now adorns the surface of the earth; but the progressive development of species more admirably adapted for the situation in which they were destined to live, is an assumption for which we have no warrant in the records of the past or present conditions of vegetable or animated nature. All is and has been admirably and infinitely wisely adapted to the conditions necessary to support and propagate life, while these conditions existed; but with a change of those, the old forms are swept away, and a new creation rises in its stead, bearing the impress of that same power, and traces of the same infinitude of wisdom and contrivance.

## ON THE TEETH OF WHEELS.

### CHAPTER II.

#### I.—TO FIND THE DIAMETER OF A WHEEL, THE NUMBER OF TEETH AND PITCH BEING GIVEN.

THE most convenient mechanical mode of solving this problem is as follows:—Set off seven times the pitch, and divide the length into eleven equal parts, thus:—Suppose the pitch to be $1\frac{1}{2}$ inch, then draw a line A B, of seven times $1\frac{1}{2}$ inch $= 10\frac{1}{2}$ inches, and divide this



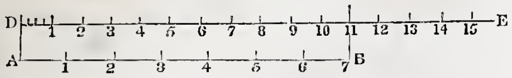

length into eleven equal parts. Now each of these eleven equal parts will count four teeth for the radius of the pitch line. Thus, if 60 teeth are wanted, measure off ten and five of those parts, equivalent to 40 and 20 teeth—giving for radius, fifteen-elevenths of $10\frac{1}{2}$ inches—that is, $14\frac{7}{22}$ inches.

The problem may be further illustrated thus:—Draw the line A B, and from the point A lay off the pitch *seven* times to B, then draw a line D E parallel to it, and say one-half longer. Upon D E mark off the length A B, and divide it into *eleven* equal parts, continuing the same scale of division farther at pleasure. (In the figure, the division is continued to 15 parts.) Now each of these divisions upon the line D E, counts *four* teeth to the radius of the pitch line. Thus, if 56 teeth be wanted, then 14 of the divisions on D E must be taken as the radius, because $14 \times 4 = 56$. If an odd number of teeth be wanted, then the first division on D E must be subdivided into *four* equal parts, each of which will count *one* tooth in the radius required. Thus, if 59 teeth be wanted, then the

radius of the wheel will be $14\frac{3}{4}$ divisions upon D, E, because $14\frac{3}{4} \times 4 = 56 + 3 = 59$.

*Example.*—Required the diameter of a wheel, the pitch being 2 inches, and the number of teeth 48.

*Fig.* 1.



Here the line AB = 14 inches; and eleven divisions upon D E, also = 14 inches; therefore, one of these divisions is equivalent to the eleventh part of 14 inches; that is $1\frac{3}{11}$ inch. Now each of these divisions, considered as units of the radius, counts four teeth, and as the wheel is to have 48 teeth, the radius will have $\frac{48}{4} = 12$ such units; that is 12 times $1\frac{3}{11}$ inch $= 15\frac{3}{11}$ inches. The diameter sought is therefore $30\frac{6}{11}$ inches.

The same may be done more simply and more directly by this arithmetical rule:—Multiply the number of teeth by the pitch, and the product by ·16 for the radius, or by ·32 for the diameter.

| | | | |
|---|---|---|---|
| Thus, | 48 = No. of teeth. | Or | 48 = No. of teeth. |
| | 2 = the pitch. | | 2 = the pitch. |
| | 96 | | 96 |
| | ·16 | | ·32 |
| | 15·36 = the radius. | | 30·72 = the diameter. |

This rule is identical in principle with that given in page 12 for finding the diameter of a wheel when the pitch and number of teeth are given. Instead, however, of dividing by 3·1416 we multiply by its reciprocal, namely, $\frac{1}{3 \cdot 1416} = \cdot 3183$ .·. or ·32 nearly for the diameter, and by $\frac{\cdot 32}{2} = \cdot 16$ for the radius. We have therefore these rules:—

$$\left.\begin{array}{r} \text{No. of teeth} \times \text{Pitch} \times \cdot 16 = \text{Radius} \\ \text{Or} \quad \text{No. of teeth} \times \text{Pitch} \times \cdot 32 = \text{Diameter,} \end{array}\right\} \cdots\cdots \text{(A)}$$

II.—From this rule for finding the radius or diameter of a wheel when the number of teeth and pitch are given, we can easily deduce the rule for finding the pitch when the radius or diameter and number of teeth are known. Thus, it is clear that if the rule (A) be true, then must the following be true also; namely,—

$$\left.\begin{array}{r} \dfrac{\text{Radius}}{\text{No. of teeth} \times \cdot 16} = \text{Pitch} \\ \text{And} \quad \dfrac{\text{Diameter}}{\text{No. of teeth} \times \cdot 32} = \text{Pitch} \end{array}\right\} \cdots\cdots\cdots\cdots \text{(B)}$$

For example, the radius being = 15·36 inches, and the number of teeth = 48, then to find the pitch we have

$$\frac{15 \cdot 36 \text{ inches}}{48 \times \cdot 16} = \frac{15 \cdot 36 \text{ inches}}{7 \cdot 68} = 2 \text{ inches pitch.}$$

The rule expressed in words is this:—*Multiply the number of teeth by* ·16, *and divide the radius by the product, and the quotient is the corresponding pitch.*

III.—Similarly, to find the number of teeth, the radius and pitch being given, we have

$$\left.\begin{array}{r} \dfrac{\text{Radius}}{\text{Pitch} \times \cdot 16} = \text{No. of teeth} \\ \text{And} \quad \dfrac{\text{Diameter}}{\text{Pitch} \times \cdot 32} = \text{No. of teeth} \end{array}\right\} \cdots\cdots\cdots \text{(C)}$$

That is,—*Multiply the given pitch (in inches or parts of an inch) by* ·16, *and divide the radius (also expressed in inches) by the product, the quotient is the number of teeth corresponding.*

As an example of the application of this rule, let the radius, as before, be 15·36 inches and the pitch 2 inches, then we have

$$\frac{15 \cdot 36 \text{ inches}}{2 \text{ inches} \times \cdot 16} = \frac{15 \cdot 36 \text{ inches}}{\cdot 32 \text{ inch}} = 48, \text{ the No. of teeth.}$$

It is hardly necessary to observe, that these rules are not *perfectly* accurate; it is impossible, indeed, to make them so; but they are sufficiently near approximations for practical purposes. When very great accuracy is required, the table at page 611 may be employed. As an example by that table, we find that the radius of a wheel of 48 teeth and 2 inch-pitch, instead of being 15·36 inches, as found by the rule above, is more nearly 15·29 inches, and more nearly still 15·2898 inches,—but even this is only an approximation.

IV.—To determine the proportions of a wheel, we have the following empirical rule:—

Divide the pitch into 15 equal parts; take 7 of these parts for the thickness of the teeth, and 12 of them for its length, namely, $5\frac{1}{2}$ from the pitch line to the point, and $6\frac{1}{2}$ from the pitch line to the root. Make the rim = the thickness of the tooth; arms = do.; and boss = in thickness to the pitch.

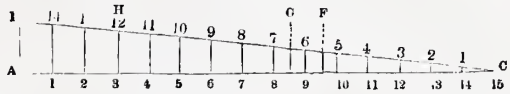
Or, by calculation, we have

$$\left.\begin{array}{l} \text{Pitch} \times \cdot 48 = \text{Thickness} \\ \text{Pitch} \times \ \cdot 8 = \text{Length} \end{array}\right\} \text{of tooth.}$$

The following is the mode of dividing the pitch into 15 equal parts, as required by the rule:—

In the diagram, fig. 2, draw the line A C, and mark off upon it 15 equal parts as required; draw A I perpendicular to A C, and

*Fig* 2.



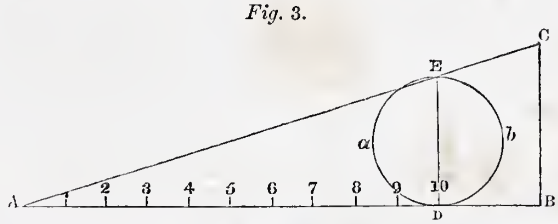
equal to the given pitch; then draw I C, and in the triangle formed draw the 15 parallels to A I, and the pitch will be divided as required.

From the diagram, to get the thickness of the tooth, set one point of the compasses at 7 in the line I C, and the other at 8 on the line A C; the line joining these points is the measure of the thickness of the tooth.

Similarly, the line H joining the points 12 in the line I C, and 3 in the line A C, is the measure of the length of the tooth; and this is equivalent to $5\frac{1}{2}$ = the line F, and $6\frac{1}{2}$ = the line G.

Another way of getting the diameter from the pitch is this,—

*Fig.* 3.



Draw the line A B = 22; then from B draw B C = 7, and perpendicular to A B. Next draw A C, and the scale is complete.

For a wheel of 10 teeth lay off the pitch 10 times to D, and draw D E parallel to B C, and it will be the diameter of the pitch circle D *a* E *b*. It will also be the radius of a wheel of 20 teeth, and half the radius of one of 40 teeth, and so on, of the given pitch.

Fig. 4 is a scale of a still more convenient kind, and ought to be constructed on a large size for general use in a workshop, as it not only saves time, but the wheels made by it are all of the same proportion of parts. The diameter of any wheel is found from it simultaneously with the thickness of tooth, width of space, &c. As here laid down the scale is adapted to wheels of any pitch, from $\frac{1}{2}$ inch to 2 inches inclusive, $\frac{1}{8}$th the size.

The method of making the scale is the following:—Draw the line A D, and from C draw C B perpendicular to A D. Transfer the divisions 1, 2, 3, 4, &c., from D E of fig. 1 to C D of fig. 4, and number the parts thus transferred 4, 8, 12, 16, 20, &c., as each division of the primary scale is equal to four teeth. Next transfer the line A I of fig. 2 to C A of fig 4, and this is equal to the pitch. Divide the line C B into 16 equal parts to B, and join B A and B D. Through the points of division on the line C B draw lines parallel to A D, terminating in A B and D B. Then each parallel from the line C B to its point of termination in D B, is the radius of a wheel with 60 teeth of the particular pitch marked against it on the line A B. Similarly, the parallels express the radius of any wheel having less than 60 teeth, when measured only to the corresponding point in the line joining B and the

divisional point on C D, against which the number of teeth is found. Thus, the radius of a wheel of 48 teeth and $1\frac{3}{4}$ inch pitch is $a\,b = 16{\cdot}36$ inches.

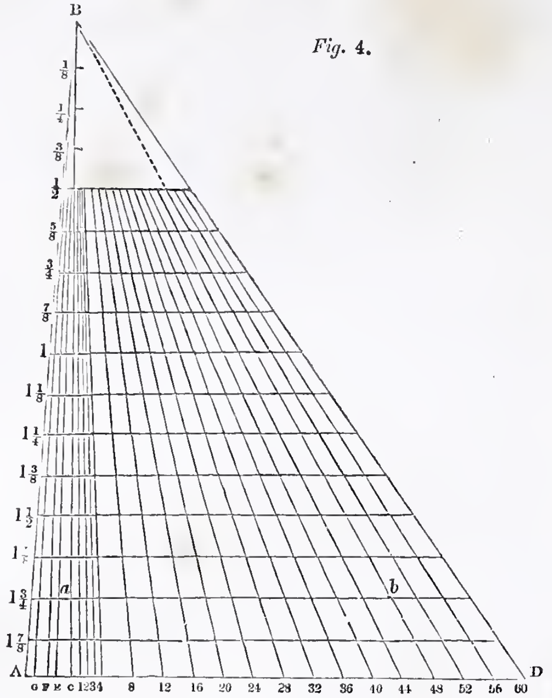


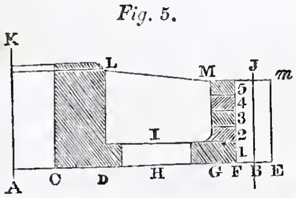

*Fig.* 4.

For the proportions of the teeth, rim, &c., set off C O equal to the length of the tooth = 12-*fifteenths* of the pitch; that is = the line H in fig. 2; also the thickness of the tooth, arm, and rim C F = 7-*fifteenths* of the pitch; the length of the tooth from the pitch-line to the point = C E = $5\frac{1}{2}$ *fifteenths* of the pitch, that is F in fig. 2; and the length of the tooth from the pitch-line to the root = E O = $6\frac{1}{2}$ *fifteenths* of the pitch; that is the line O in fig. 2.

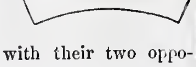
This scale may be used when the number of teeth exceeds 60; thus, for a wheel of 92 teeth and 2 inch pitch, the radius is found by setting off in the compasses the whole line C D, and also that part of it from C to the point marked 32. For odd teeth make use of the first four divisions, as explained under fig. 1.

V.—*To set off a spur-wheel with 32 teeth and 2 inch pitch.*—Draw a line A B; take A as a centre, and lay off A B = the distance from C to 32 on C D of fig 4; that is = the radius of the pitch circle. Through the points A and B, and perpendicular to the line A B, draw the lines A K and B J. From A, the centre, set off the radius of the shaft = A C; and from C lay off the pitch = C D for the thickness of the boss; then with the distance C E of fig. 4 in the compasses, set off B E for the length of the tooth from the pitch-line to the point; and in like manner, with the distance E G of fig. 4 in the compasses, set off B F for the length of the tooth from the pitch-line to the root. Again, from F set off F O = C F of fig. 4 for the thickness of the rim; and upon B J set off the width of the tooth, and upon A K the length of the boss; draw K L and D L to define the boss. Also draw M $m$ parallel and equal to G E, and join M and L. H I is the face-bar.

*Fig.* 5.




Next divide the width of the rim into as many parts as there are thicknesses of timber in it, 1. 2, 3, 4, 5, the face-bar being broader and thicker than the others. The diagram annexed is the form of the templet for cutting out the deal 2, 3, 4, 5, into 8 lengths each. This templet should of course be quite dry, and free of shakes. The arms are next to be cut out of the requisite width, with their two opposite sides quite parallel, so that they can be fastened properly to the face-plate in turning the outside of the rim.

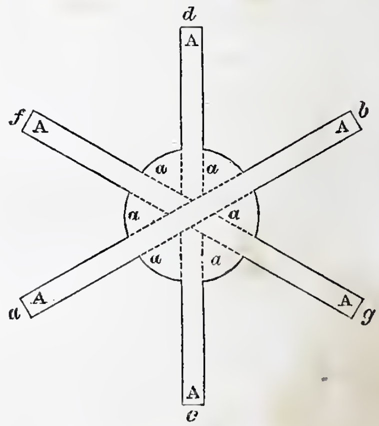


In gluing up the rim, fix a wooden face-plate of sufficient size to take in the diameter of the rim which is to be marked upon it, on the iron one of the lathe, and turn it up perfectly true. The size, however, must be kept slightly greater than the diameter of the rim to allow for subsequent dressing. This done, clean one side of the segments marked 1, in fig. 5, and fit them to the face-plate; joint their ends and sprig them on temporarily to the face-plate. When they are thus all fitted on, take them off, one at a time, and glue paper betwixt them and the face-plate; fasten them with sprigs which are to be left in such a way as to be easily pulled out with the pincers when the glue is set. The segments 1 are next to be turned on the face, and segments 2 fitted on in the same manner. Afterwards in succession the segments 3, 4, and 5, always observing, as the sprigs are pulled out, to fill the holes with wooden pins and glue.

When the glue is quite hard the rim is to be turned to the proper width, and also on the concave or inside according to the drawing, allowing a little taper to make the pattern leave the sand freely when moulded. When the inside is finished, the rim may be taken off the face-plate by forcing a thin chisel betwixt it and where the paper is glued; the paper will split and let the rim free. To ensure this, the paper must be glued on in narrow slips, three of them to a segment, crossways.

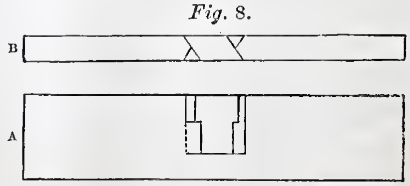
For turning up the outside of the rim and teeth, and pitching the teeth, an iron face-plate must be used, of a suitable diameter, and provided with slots and holes in it for screws, so that 4, 6, or 8 arms can be screwed on; likewise a recess in the centre about three inches diameter, and half an inch deep, with a plate of iron to fit it, for adjusting the arms to the centre. When these are scarfed, and blocked at the centre to strengthen them, as shown in the annexed diagram where A A . . . . . . are the arms, and $a$, . . . . the strengthening blocks, screw the small iron-plate upon the centre of the arms, and having fitted this into its recess in the centre of the face-plate, the arms are next to be firmly bolted also to the face-plate. Reduce the arms to the exact length, and so that one shall not be longer than another, and fit the rim upon them; screw the face-bar of the rim to the arms, and glue or sprig two small blocks temporarily, one on each side of an arm, on the other edge of the rim, so that the arms can be taken off when it is turned. It is not necessary to fit in the face-bars of the arms until the teeth be all finished, at least in spur-wheel patterns.

*Fig.* 7.




It must be understood that the three pieces in fig. 7, forming the six arms, are sunk flush into one another, from which it follows that the depth of each piece being divided in three parts, two of these parts must be scarfed out for the reception of the other two pieces. Thus in the diagrams of fig. 8, that marked A

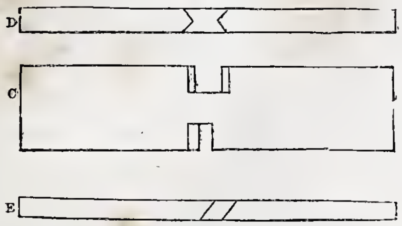
*Fig.* 8.




is a side, and that marked B an edge view of the two outside pieces $a\,b$, $c\,d$, of fig. 7; and similarly, C, D, E, of fig. 9, are one side and two edge views of the middle piece $f\,g$. The manner

in which the scarfings close with one another, is observable in the external view of the centre in fig. 7. We see then that a

*Fig.* 9.



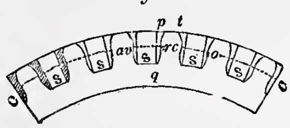

third of the width is left in scarfing, and this is necessarily the case when the pattern has six arms; were it formed with four arms, one half the breadth would be left, and only a fourth were the pattern made with eight arms.

When the outside of the rim is turned up according to the drawing, the next business is to divide or pitch the rim into as many divisions as there are teeth required. These divisions are to be carefully marked off by lines drawn upon the rim across its breadth. There are two modes of attaching the teeth; either they may be fixed by screws with glue, or they may be dovetailed into the rim. This last is decidedly preferable for large wheel patterns, and in shops provided with such a machine as that described at p. 348, for wheel-cutting, it is found to be by far the most expeditious mode. When the pattern is small and of small pitch, the teeth may be simply sprigged on with glue.

The teeth ought to be of hard wood, such as plane-tree, or beech. Baywood and cedar are also used; but plane-tree is preferable at least for small wheels.

The teeth being blocked and fixed lengthways across the rim with glue, pieces of half-inch deal are then glued betwixt the teeth; these pieces are marked *s s* . . . . in fig. 10, and their use is to prevent the ends of the teeth being split in turning. When the glue is dry, the teeth are to be turned to the width and length required: the pattern is then ready to have the pitch circle *c c* drawn upon it.

*Fig.* 10.




This circle being accurately and finely drawn, the next business is to divide or *pitch* it into 32 equal parts of two inches; that is, from A to C on scale fig. 4. The radius in this case will be very nearly $10\frac{1}{2}$ inches, that is from C to 32 on the scale line C D. The curves of the teeth are next to be described; the pitch in this instance is the radius from the pitch-line both to the point and root of the tooth; that is, one leg of the compasses being placed at *o*, fig. 10, the other opened two inches will describe the curve *r p*, and placed on *a*, will describe the curve *r q*. From *r* to *c* set off the thickness of tooth equal to G E in fig. 4, and describe the curve *c t* from *v* as a centre. Draw in the other curves in the same manner, and when they are set out on one side, square the lines across to the other side at four points taken consecutively at right angles to each other; set out that side in the same way as the other, taking particular care that the lines upon both sides accurately correspond in position, otherwise the teeth will twist, and will neither leave the sand clearly in moulding, nor work well when cast.

Fig. 10 shows part of a wheel after being turned and set out, with the teeth drawn upon it preparatory to their being cut.

*Fig.* 11.

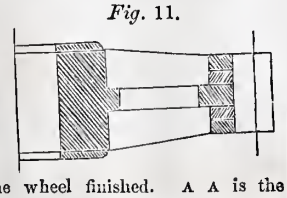


Fig. 11 shows in section the mode of constructing a wheel with the feather-bars in the middle—the feathers of the arms and rim being glued on when the wheel is being built up on the face-plate.

Fig. 12 shows one-half of the wheel finished. A A is the pitch circle; *r* the root, *p* the point, and *r p* the length of tooth; D D, the rim of wheel; H, face-bars; F, arms; G, boss.

VI.—To set out a pair of bevel-wheels, one with 44, and the other with 32 teeth in accordance with scale fig. 4.

*Fig.* 12.

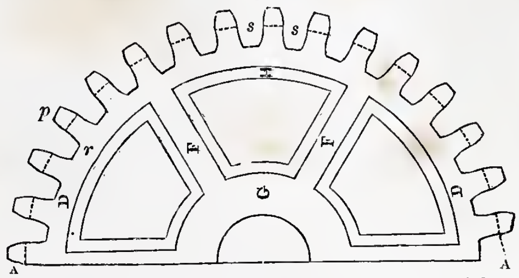
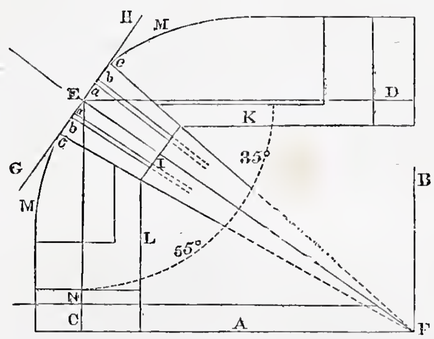



Fig. 13. Draw the lines A and B, so as to form a right angle

*Fig.* 13.




with each other at F; on the line A set off the radius or half the diameter of the large wheel from F to C, and the radius of the other from F to D; from the points C and D draw the lines C E and D E perpendicular to the lines A and B, and forming a right angle at their point of intersection E; draw the diagonal F E, and through the point E draw G H, so as to intersect it at right angles. Next, lay off the length of the tooth from the pitch-line to the point from E to *a a*, and also the length from the pitch-line to the root from E to *b b*; the thickness of the rim from *b* to *c*, and the width from E to I; then draw the line I parallel to G H, and produce the lines *a a*, *b b*, *c c*, from the points marked upon G H to I, so that, were they continued, they would meet in F as a centre. From *a* to *b* is the clearance of tooth from point to rim when the wheels are working to the pitch-line. Draw the lines K and L, and from them set off the thickness of the face-bar, arm, &c., as already described under fig. 5; and finally describe the curve M M, so as to touch the back of the arms.

The dotted curve shows the angle at which the wheels are to work — the larger one at an angle of 35 degrees, and the smaller one at an angle of 55 degrees. Their ratio is 8 to 11, and is thus found: set down the number of teeth in the wheels, and find their least common multiple; that is, the least number which can be divided by both numbers without remainder; in this case the least common multiple is 352, then $\frac{352}{44} = 8$ and $\frac{352}{32} = 11$, and the quotients 8 and 11 express the ratio.

Or the ratio may be found more conveniently by finding the greatest common measure of the numbers; that is, the greatest number which will divide them without remainder, and dividing the number of teeth in each wheel by it; thus 4 is the greatest common measure of 44 and 32, and the quotients of these numbers by 4, are 11 and 8.

It is hardly necessary to observe, that it often happens that a pair of wheels have no other numbers to express their ratio than their respective numbers of teeth; thus the ratio of a pair having respectively 27 and 53 teeth, is expressed by those numbers, seeing they have no other common measure than 1.

Any other pair of bevel-wheels may be set out in the way described. Thus, supposing a wheel of only 28 teeth was required

to work into the one of 44; from the point E to N, lay off the radius of the smaller wheel, and draw the line N at right angles to the line N E till it meets the line F E, upward as before.

Fig. 14 shows the manner of gluing up the rim. The segments No. 1, are glued to the face-plate with paper betwixt, and Nos. 2, 3, 4, are glued on so as to project over as shown in the figure, and so that the bevel can be obtained. The inside is turned up to *c c* of fig. 13; likewise the inside and outside edges. The rim is then taken off the face-plate. The arms are to be fastened to the iron face-plate, in the same manner as in making spur-wheel patterns, with face-bars upon them. Some, however, put on back-bars instead of face-bars, and then the arms only are screwed upon the face-plate. The arms being reduced to the proper length, the rim is then fitted upon them and turned on the outside, like the quarter A, in fig. 15, ready for the teeth being glued on.

*Fig* 14.

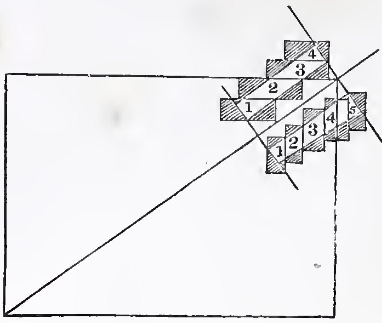
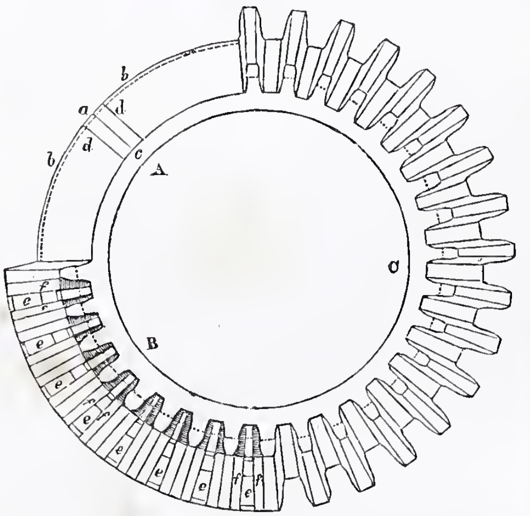



*Fig.* 15.




The dotted circle is next to be drawn to divide or pitch the rim by; from the point *a*, the equal distances *b*, *b*, are marked off, and from these points small arcs intersecting in *c* are described; the points *a* and *c* being joined, we have the line *a c*, as the square line or axis of the tooth. From *a c* lay off half the thickness of tooth on each side to *d*, *d*; from *d* divide or pitch the rim upon the dotted circle into as many parts as there are teeth required; set a bevel to the line *d*, and draw lines across the rim at all the divisions to fix the teeth by; these being glued and sprigged on, set pieces of deal between them to prevent their splitting when being dressed in the lathe. The quarter of the wheel marked B is turned up with the teeth set out; *e*, *e*, are the pieces betwixt the teeth; *f*, *f*, superfluous wood to be cut away; C is one half of the wheel finished.

In setting out a bevel-wheel, the teeth are drawn over to the inside in four parts, as in a spur-wheel pattern. To obtain the pitch of the inside, two or three teeth should be drawn over, and, as a precaution, at least one quarter should be tried in case of inaccuracy.

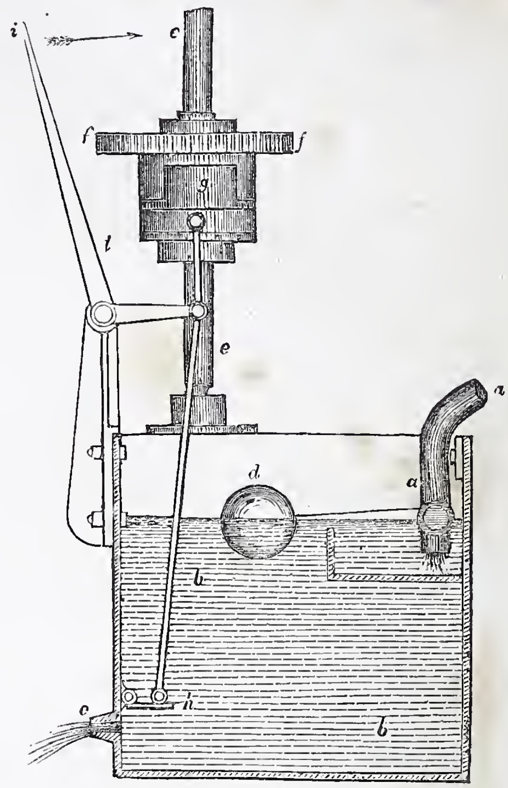
AMICUS.

## SELF-REGISTERING WATER METERS.

By Mr. James Whitelaw.

In fig. 1, *a a* is a pipe which supplies the cistern *b b* with water, and *c* is an outlet for the water. The stop-cock in the pipe

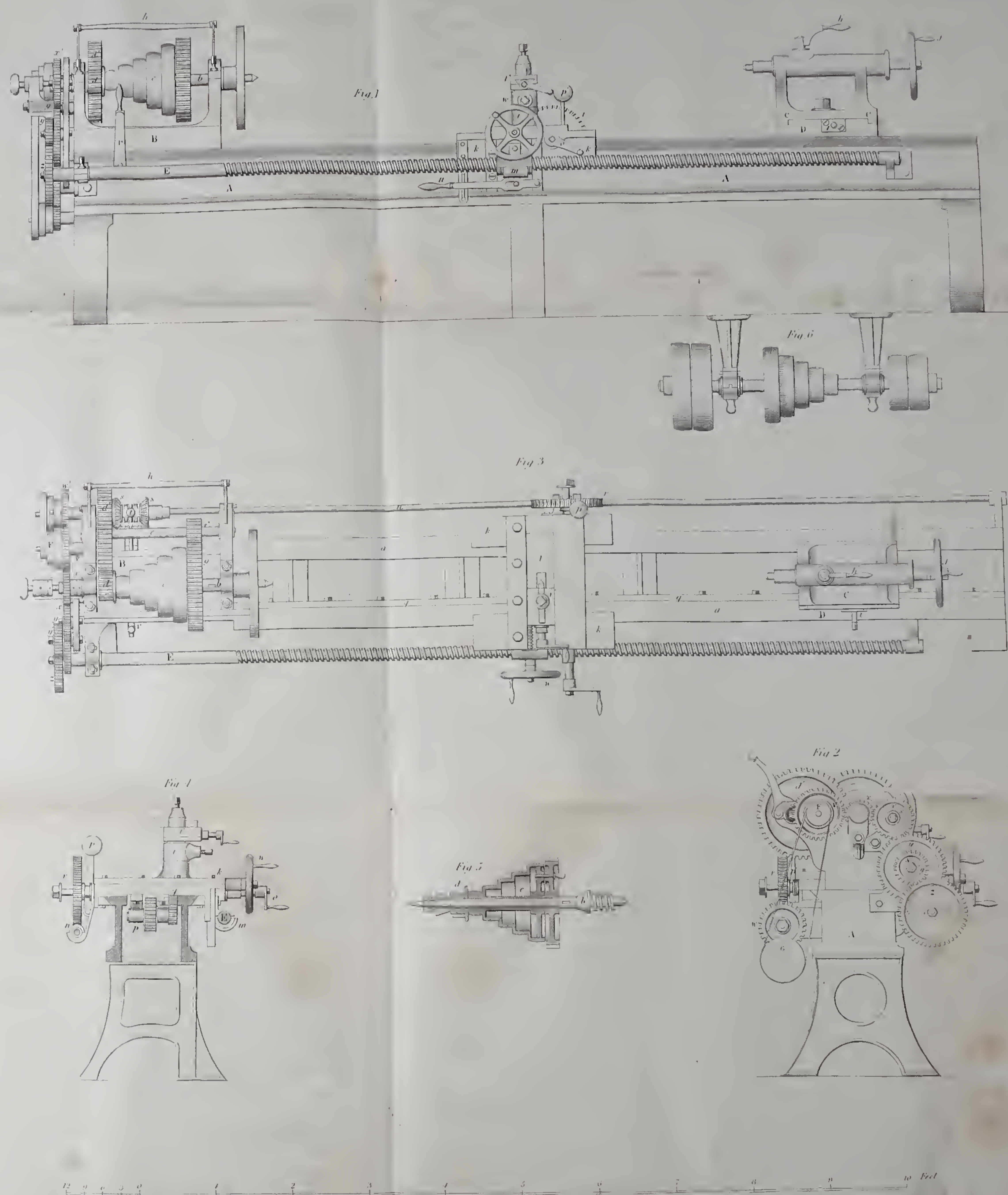
***Fig.* 1.**

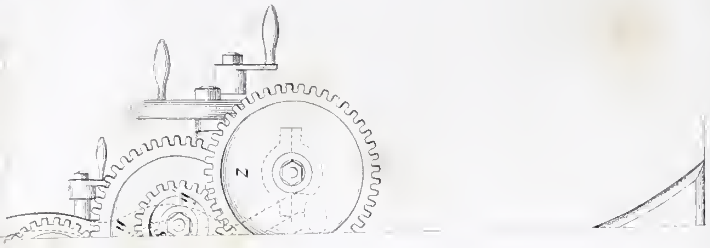



*a a* is regulated by the float *d*, in order to keep the surface of the water in the cistern at nearly the same level at all times. The spindle *e e* is kept in motion by a clock, and the spur-wheel *f f* works loose on that spindle when the catch-box *g* is pulled out of gear; but, when the catch-box is in the position shown in the figure, the wheel *f f* revolves along with the spindle. *i i* is a handle for opening or shutting the valve *h*, and, at the same time, putting the catch-box into or out of gear with the spur-wheel *f f*.

The arrangement of apparatus for effecting these ends will be understood from an inspection of the figure. Suppose the parts in the position shown, the quantity of water which will flow out at the aperture *c* will be the same in equal times if the level of the surface of the water do not vary; and one of Woolfe's counters will, if it be properly graduated, and worked by the spur-wheel *f f*, point out the quantity of water which passed from the aperture *c* in any time. If the distance from the surface of the water to the centre of the aperture *c* be very considerable, a slight variation of the height of that surface will not cause any great change in the velocity of the water issuing from the aperture *c*. The float and the parts in connexion with it may be constructed in such a manner that they will maintain the surface of the water at very nearly the same level, even if the degree of pressure in the pipe *a a* were different at one time from what it is at another. If the handle *i i* be turned in the direction of the arrow, the water and the counter will be stopped. If the pipe *a a* were supplied from a cistern, the height of the water in which was regulated by a valve and float, an apparatus of the kind shown would measure the quantity of water which escaped from the aperture *c* to as great a degree of accuracy as would be required for any or-

SMALL SLIDE and SCREW CUTTING LATHE By M^R. CHARLES WALTON LEEDS.




Z
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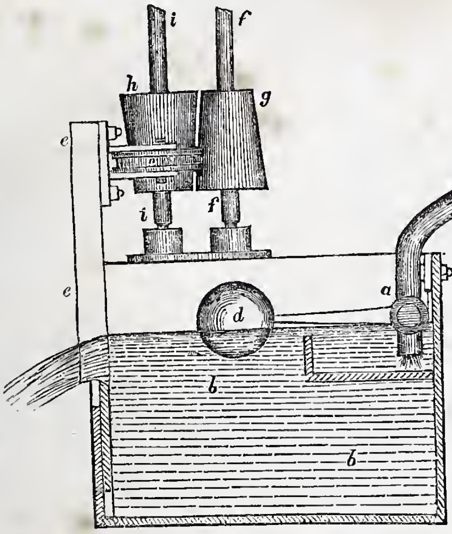
dinary purpose. The additional cistern will of course only be required in cases where the pressure in the pipe *a a* would vary to a very considerable extent without it, and in cases where great accuracy is required. The prongs on the catch-box should be so long as not to allow the valve *h* to open before they gear into the corresponding spaces on the underside of the wheel *f f*. The catch-box should perhaps have a greater number of prongs than is shown in the figure, and the levers, &c., might be so contrived that, whenever the handle *i i* is shifted into the position shown in the drawing, a weight or spring would connect the catch-box with the

*Fig. 2.*




wheel *f f*, and also open the valve as soon as the prongs came opposite the spaces into which they gear.

The apparatus described above will measure the water if it be used in a regular stream; but if it should not be convenient to take always the same quantity of water in equal times, a meter like that shown in fig. 2 will be required. In this figure, *a a*, *b b*, and *d*, point out the same parts as in the other drawing; *c e* is a notch or weir which must be raised or lowered by a screw or by some other means, till a stream of a suitable depth passes over it. The spindle *f f* and the cone *g* are worked by a clock all the time the water is running over the weir, and motion is communicated to the counter by the spindle *i i*, which has a cone *h* fixed on it. The guide-pulley *n*, and another guide-pulley, which is placed on the opposite side of the cone *h* are fastened by brackets to the top part of the weir *e e*. A strap works upon the guide-pulleys now spoken of, and passes betwixt the cones *g* and *h*, and as these cones are pressed towards each other by a spring, the cone *g* will, by its action on the strap, communicate motion to the cone *h*. The motion of the cone *g* being uniform, the speed of the cone *h* will not be so great when the strap is working near the top end of the cones as it will be when the position of the strap is lower, and as the weir and strap, from the way in which they are connected, must rise or fall together, the quantity of water running over the weir will be less when the cone *h* and spindle *i i* are revolving at a slow rate than it will be when the motion of these parts is quick. From this it is clear that the counters will point out the quantity of water expended, if the cones have such a form or taper as will cause the speed of the spindle *i i* always to be in exact proportion to the quantity of water expended, whatever may be the position in the weir. The shape of the cones may readily be calculated; but, in the mean time, it is sufficient to remark that any form may be given to them, provided the motion of the strap, up or down, in relation to that of the weir, be made to correspond.

## SMALL SLIDE AND SCREW-CUTTING LATHE.

By Mr. Charles Walton, Tool-maker, Leeds.

*(Illustrated by Plate.)*

Fig. 1 is a front elevation.
Fig. 2, an end elevation.
Fig. 3, plan of the lathe.
Fig. 4, front elevation of top-driving apparatus.
Fig. 5 is a section of the cone and spindle of lathe.
Fig. 6 is a representation of the driving cone.

A A is the cast-iron bed, with the top flanges *a a* planed true. The bed is bolted fast upon cast-iron standards. B B is the fast headstock; it is fastened to the bed by bolts, and carries the case-hardened spindle *b*, which revolves in conical collars of hardened steel. Upon the spindle *b* is the driving-cone *c*, with pinion *d* of 13 teeth fast upon the end of it; this last communicates motion to the wheel *d'* of 52 teeth, which is fast on the back-shaft *e*—shown in the plan, fig. 3; and on the same shaft is pinion *f* of 13 teeth, giving motion to the wheel *g* of 52 teeth, which is fastened on the spindle *b*. By these wheels and pinions being all in gear, a reduced motion is given to the spindle *b*. The wheel *d'* and pinion *f*, which are fixed on the back-shaft *e*, being thrown out of gear by the rod *h*, and the cone *c* made fast to the wheel *g*, the spindle then receives the same speed as the cone.

C C, moving headstock. This is planed and fitted on a saddle, D, which again is planed and fitted to slide on and betwixt the flanges of the bed A A—the head and saddle being bolted to the bed in the ordinary way. The head C C, by means of the side-screw *i*, can be moved on the saddle D at right angles to the bed A A, thereby adapting the machine to conical turning. The spindle is adjusted by a screw worked by the wheel *j*, and is held fast by the screw worked by the handle *h*.

E, the leading screw communicating motion to the sliding-saddle, *k k*, containing the slide-rests, *l*, *l'*, for screw-cutting; the screw receives its motion from a train of wheels communicating with the spindle *b*, (shown in figs. 1, 2, 3,) and the screw box *m*, which can be opened at pleasure by the handle *n*; and when the screw-box *m* is open, it allows the sliding-saddle *k k* to be shifted by hand, by turning the handle *o*. The motion is communicated to it by means of the spur-wheel *p* of 10 teeth, (seen in outline in fig. 2,) which communicates with the rack *q q*; this rack has its teeth turned downwards, which prevents the iron turnings from lodging in it. The slide *l* is moveable in the saddle to suit different diameters; it is moved by the wheel *w* and screw, shown in fig. 3, which is used for surfacing work, and is worked by hand, or made self-acting if required; likewise the slide *l'* has a small box fitted to it, to carry the cutters, and which can be set at any angle required; this makes it very convenient compared with the ordinary mode of fixing the cutter.

The train of wheels communicating with the spindle *b*, and which gives motion to the leading screw E, consists of the wheel *x*, of 40 teeth, fast upon the spindle *b*, and working into the carrier wheel *x'*, of 60 teeth, upon a shifting stud S; this last gears into a wheel *y*, of 90 teeth, upon the shifting stud S'. Fast upon the pap of this wheel, is a wheel *y'* of 45 teeth, which gears into the wheel *z*, of 90 teeth, upon the end of the leading screw. This train may of course be changed at pleasure to suit the particular motion of the leading screw wanted. The leading screw has four threads to the inch.

*k k*, the sliding saddle for regular sliding, receives its motion from the main spindle *b*, by means of a train of wheels and small cones F G, connected by means of a leather belt, which gives motion to the wheels connected with the traverse rod *n*, (shown in fig. 3,) and which has on it a sliding worm that drives the wheel *r*, and which is moved in or out of gear by the handle or lever *p'*.

The train for giving motion to the traverse rod *n* is this:—the wheel *x*, upon the main spindle *b*, gears into a wheel *v'*, of 72 teeth, and which is fast upon the axis of the cone F. This cone is connected with the cone G by a belt. Fast upon the axis of the cone G is a pinion of 20 teeth, which gears with the wheel *w'*, of 72 teeth, upon the end of the traverse rod.

The gearing for reversing the saddle when sliding, is shown in fig. 3; it consists of three meter wheels *s s s*, and clutch box, and the spanner *t*, fixed on the shaft *u*, which passes through

the bed A, to the front side, where is a reversing handle *v*, fixed on a lever passing in front of the lathe.

Fig. 4 is the front elevation of the top-driving apparatus for the lathe: it has two sets of pulleys, the smaller pulleys being used in reversing the saddle when cutting screws, and the larger pulleys when a slow motion is required for the lathe.

## HAND PUNCH AND SHEARING MACHINE.

By Mr. Charles Walton, Tool-maker, Leeds.

*(Illustrated by Plate.)*

This machine is adapted to punch holes up to $\frac{3}{4}$ of an inch diameter in wrought-iron plates $\frac{3}{8}$ of an inch thick, at any distance from the edge not exceeding $7\frac{1}{2}$ inches, and to shear plates up to $\frac{3}{8}$ of an inch in thickness (without curling the piece sheared off), and will admit of cutting a plate 12 inches broad.

Fig. 1 is a side elevation.
Fig. 2 is a front elevation.
Fig. 3 is a projection on A A to receive the die.
Fig. 4 is an end view of the spindle F, and caps L L.

*Description.*—A A is the body part of the machine, made of cast-iron; B is a cast-metal fly-wheel, 5 feet diameter, with a cast-metal pinion C of 12 teeth cast fast to the wheel; the fly-wheel and pinion together revolve on a strong stud fastened into the body part of A A by means of two cutter keys; the pinion C drives the wheel D of 90 teeth, which is fastened on the shaft E, which revolves in two bearings and bushes in the body part A A; these are also retained in their places by a cutter-key over each bearing; the end of the shaft E is formed into an eccentric, and has a bush on it that works in the opening of the spindle to give the required length of stroke to spindle F, which holds the punch *a* at the bottom end, and at the top end the cutter *b*, which passes in front of the cutter *c*, fastened to the jib end of A A: *d* is the steel die for punching over; and L L are two caps which keep the spindle F in its place by means of bolts and nuts.

## DESCRIPTION OF LATHE CHUCKS.

*Arbor Chuck.*—The form of this chuck is represented by fig. 1; it is used for turning cylinders, tubes, pulleys, and the like, where the inside and outside surfaces are required to be perfectly concentric.

*Fig.* 1.

As the diameters of the holes in work of the kind to which this chuck is applicable, vary very considerably, a number of sizes of arbor chucks are required; but, from its simplicity, one of larger size is readily turned down to fit the work, and a little fixing only is necessary to support it whilst turning.

Should the work be longer than can be supported by the chuck alone, it is necessary to bring the front centre against the other end; and when the work is a tube or cylinder, with which this cannot be done, it is only necessary to insert into the work a plug having a hollow centre to fit the chuck. This arrangement is shown in fig. 2.

*Fig.* 2.

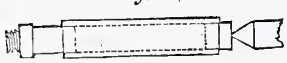
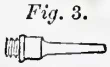


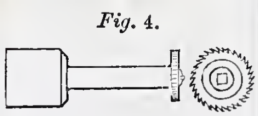
*Fig.* 3.



The arbor chuck for large work is usually made of iron; for small metallic work it is commonly of brass; but for small articles of brittle material, as wood, ivory, &c., it ought to be formed of wood. When the article to be turned is very small, and the material hard, an arbor chuck of the form shown in fig. 3. is employed; this, for beads and the like, is made of steel.

*Arbor chuck with circular cutters.*—This chuck has a flanch socket, screw, and nut, for receiving circular cutters, or saws—which are made of various forms and sizes, and by means of which circular cavities and grooves may be cut in metal, of various forms, dependent on the size and shape of the cutter. It somewhat resembles the seal engravers' engine, and similar tools have also been used by dentists in making artificial teeth. It is also used for cutting the grooves for the springs in telescope tubes.

*Fig.* 4.



These cutters are found very useful for excavating metal, wood, ivory, &c., for various purposes, either transversely or lengthways, and of course the cutters make the reverse of their own form.

*Arbor chuck with cone and screw.*—This chuck is for turning the outside of any work having a hole in it. It is particularly useful in turning the outside of hollow pieces of ivory, &c., which have their sides of unequal thicknesses, as it saves the trouble of preparing them with a file, or any other instrument. It is similar in some respects to the chuck last described, having a flanch socket, nut, and screw, but differing in the washer, which, instead of being a flat surface, is a cone, and therefore is capable of holding work, having a hole of any diameter within the two extremes of the cone. Besides the flanch socket, nut, and screw, it is provided with brass washers to place between the flanch and the work to make the chuck suit various lengths.

*Fig.* 5.

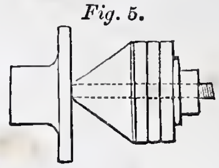
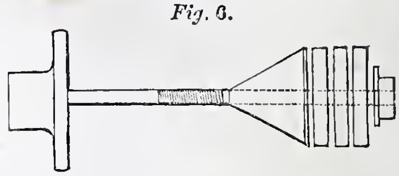
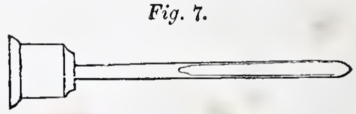


*Fig.* 6.



*Boring chuck.*—The boring bits are each fitted in a chuck,

*Fig.* 7.



and are adapted for boring wood, metal, ivory, they may be applied, of any size, and of the form most suitable to the kind of material to be bored.

*Branch chuck with four branches and screw-heads.*—The form of this chuck is shown in the annexed figs. 8 and 9. It has four arms *a;* each arm has a groove lengthways with bevelled edges, and in each of these grooves is fitted a brass popit head *b*, similar to the front centre of the lathe. These heads are provided with screws and washers underneath, by means of which they can be made stationary at any part of the groove. The upper part of the brass head is provided with a steel centre screw *c;* the head has also a slit lengthways, about two-thirds the whole length, and a tightening screw *d* on the side, by means of which, owing to the slit, the centre screw *c* can be made immovable. This chuck is for holding work either from the inside or outside: should the work require that one side project more than the other, it can readily be done by shifting the centre screws accordingly.

*Fig.* 8.

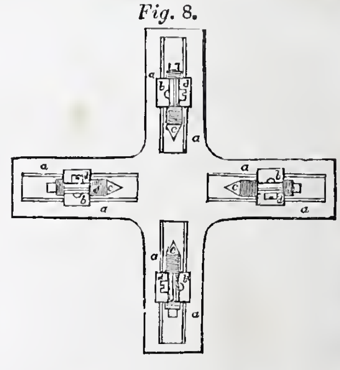
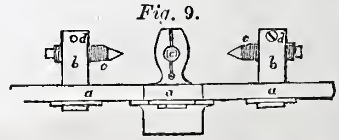
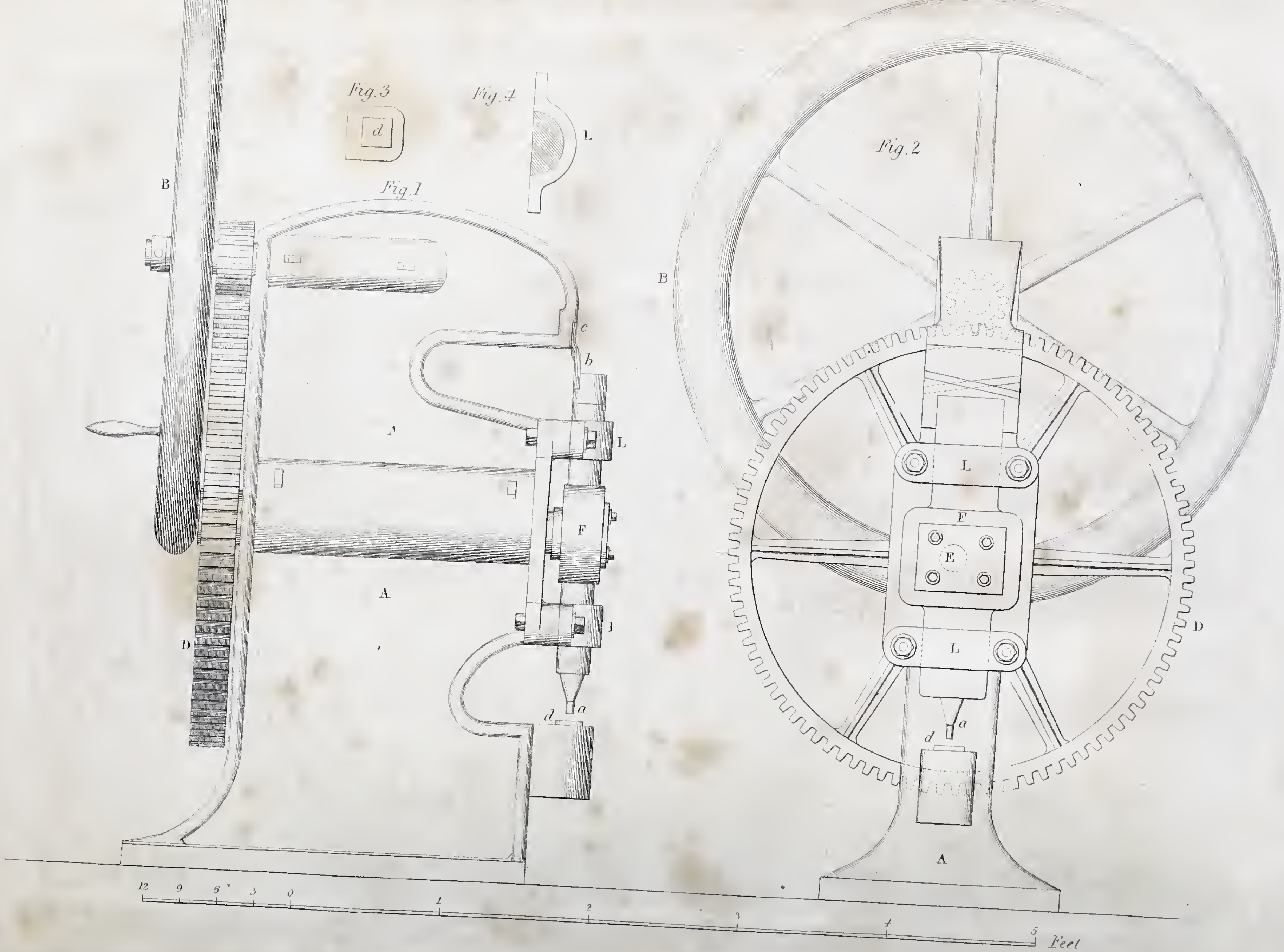


*Fig.* 9.



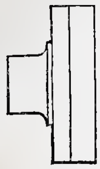
*Cement chucks.*—The general form of this chuck is shown in fig. 10. It is provided with a thick coating of cement;

WALTON'S HAND PUNCH and SHEARING MACHINE.



ment; when used the cement is warmed by a hot iron, or any other heat without flame, until the cement begins to melt, and then it should be spread equally over. The work, supposing it to be metal, should also be warmed and laid upon the cement on the chuck whilst both are warm; the chuck must then be screwed on the lathe, and the cement not being quite cold, the work can be shifted till that part of it be in the centre that is required.

*Fig.* 10.



Cement is also frequently used on wood chucks, the chuck must first be turned true, and a few jags or scratches with a pointed tool made on it; this chuck being made to revolve on the lathe with considerable velocity, a stick of cement held against it will be partially melted and will adhere to the chuck. The wood to be fixed must be held against it, and, by turning the lathe quickly, the eement will be again melted and nicely spread over each surface; before the cement cools, the work must be adjusted centrically. This requires expeditious treatment. Chucks of this kind hold work very firmly, but will scarcely bear the slightest jirk.

*Clamp chuck.*—Two views of the form of this chuck are given in figs. 11 and 12. It is provided with five sets of holes for the three screws and rings, all at regular distances from the centre and from each other, for suiting large and small diameters. It is intended to hold thin substances, whether round or any other figure; and by means of the three screws and rings, any part of the work may be brought to the centre that may be wanted. This arrangement is found very convenient for surfaces that require to have holes made in them at right angles, and which is very desirable in framing brass, steel, or wood work, for machinery or other purposes. Occasionally these chucks are fitted up with small steel plates, with a hole in the centre for fixing any work such as a ring, in the centre of the chuck, somewhat in the same manner as the arbor chuck with cone and screw.

*Fig.* 11.

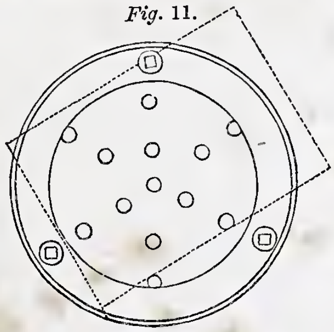
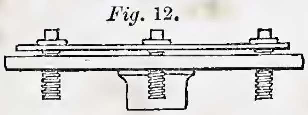
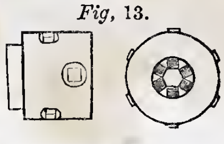


*Fig.* 12.



*Die chuck with six screws.*—Fig. 13 embraces two views of the form and construction of this chuck, which is very useful in turning hard substances, such as steel, iron, brass, &c., where the front centre would be in the way, it being very improper to fit such work in wood, as the great heat given to it in turning or boring, is very apt to warp or expand the wood chuck, thereby allowing the work to get loose in it.

*Fig*, 13.



There is some difficulty in fixing work in this chuck, but the readiest way is to set it true first with the three back screws, (the three front ones being entirely disengaged,) and then screw the front ones tight, equally, so as not to disturb the first position of the work.

*Die chuck with slides.*—This chuck has two steel slides *a*, working in dovetailed fittings. To prevent their coming out they are encompassed by a brass ring, *b*, which is secured to the chuck; in this ring are two screws *c c*, with square heads to press forward the slide *a a*, thereby fixing the work between their ends—which are of an oval form to suit a variety of diameters.

*Fig.* 14.

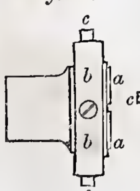
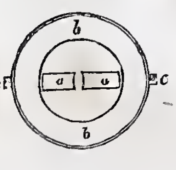


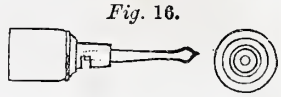
*Fig.* 15.



Small pieces of ivory, metal, &c., may be turned in this chuck.

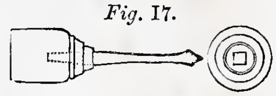
*Drill chuck with round hole and drills.*—This chuck has a steel socket fixed in front, with a cylindrical hole in it. The drills to fit this chuck must of course be of a corresponding cylinder. Both the drills and socket being round, it follows that any strong resistance employed would cause the socket to revolve, and the drill would remain stationary; to prevent this, the socket has one half of its substance filed away where the hole ends, (as shown in the fig.); the drill also has one half of its substance filed away in a similar manner, (as also shown), so that when the drill is put in the socket with its remaining lip opposite the side which is cut away, there being nothing to impede it, it slips over the flat surface in the drill socket, and the two halves form as it were a single piece; thus the drill is caused to revolve with the socket. To take the drills out of their socket, a lever is put between the end of the drill and the shoulder of the chuck below it, and by this means it is readily forced out of its place.

*Fig.* 16.



*Drill chuck with square hole and drills.*—For strong work, the drill chuck with round hole and drills last described, is not so well adapted, but in the square hole, the drills bear equally on the whole length of each side, which renders it much stronger.

*Fig.* 17.



Care is necessary in putting the drill into the chuck, to set the side of it marked with a dot opposite the side of the chuck marked in the same way.

To drive the drill out of its place, a pin must be used from behind.

*Eccentric chuck.*—Figs. 18 and 19, are two views of this form of chuck. The screw *a* is of the same thread as the screw of the sliding rest; it has ten threads to the inch, and the screw-head is divided into 10 equal parts, therefore $10 \times 10 = 100$ equal parts to the inch; therefore one division of screw-head is equal to the hundredth part of an inch. To turn a surface, the eccentric chuck is used like a common chuck; the pin *b* is put in from behind, and the screws *c c*, are loosened, to set the collar *d* at liberty, without which it would strain the centre of the chuck. But previous to eccentric turning, the pin *b* is taken out, and the screws *c c*, are made tight to fasten the brass collar *d*. It will be found most convenient in beginning all eccentric work, for the centre of that work to be perfectly true with the axis of the lathe, in that case the graduated head of the screw *a* will point to 0, and the click of the chuck should point to 96.

*Fig.* 18.

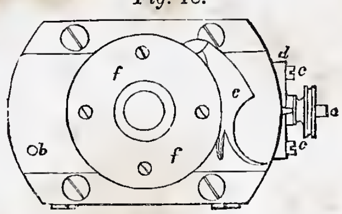
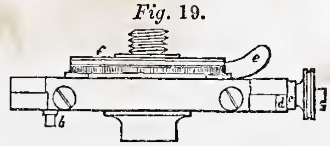


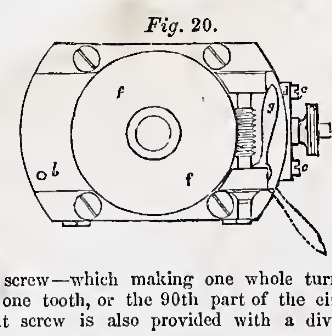
*Fig.* 19.



*Eccentric chuck with endless screw.*—The annexed fig. 20, represents this chuck. It differs from that described above only in the circular motion. The wheel *f f*, figs. 18 and 19, has 96 oblique teeth, which are regulated by a click *e*, which acts in them.

In fig. 20, the wheel *f f*, has 90 teeth, cut with a screw on the circumference. This wheel is worked by a tangent screw—which making one whole turn, the wheel *f f* is moved one tooth, or the 90th part of the circumference. The tangent screw is also provided with a divi-

*Fig.* 20.



sion of 8; therefore while the screw is moved through one of these divisions, the wheel will be moved $\frac{1}{720}$th part of a circle; that is, $90 \times 8 = 720$ parts. The tangent screw is kept in its place by the lever *g*, when it is in the position of fig. 20; but when it is in the dotted position, it allows the screw to disengage itself from the wheel—which can consequently turn round without interruption.

*Flanch chuck with dogs.*—Two views of this chuck are given in the annexed figs. 21 and 22. It consists of a flat plate which

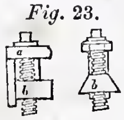
*Fig* 21.

*Fig.* 22.

screws on the end of the mandrel; it has six dovetailed grooves cut in it, three near the centre, and three near the circumference.

The dogs mentioned in the name, are shown at figs. 23. They consist of three pieces of steel *a*, shaped like right angles, having each a screw passing through the top; these screws fit into the dovetail blocks *b*, which exactly fit the dovetail fittings, the tail or straight part of the piece *a*, passing at the same time through the grooves of the chuck; by this means, flat pieces, rings, &c., not exceeding six inches diameter, and one inch thick, down to the size of a shilling, may be securely fixed either at, or from the centre, as may be desired.

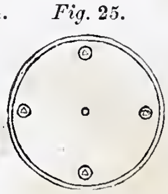
*Fig.* 23.



*Flanch Chuck, with Points.*—The form of this chuck is shown in figs. 24 and 25. It is composed of a brass plate, having five steel points in it—one at the centre, and the other four at equal distances round it. This chuck is for roughing out soft wood. The work is driven on with a hammer, and supported at the other end by the front centre. It is found convenient for turning the outside true, fit for turning in a plain chuck, &c. To use it in turning hardwood, &c., the hole in the work must be drilled up.

*Fig.* 24.

*Fig.* 25.



*Oval Chuck.*—The construction of this chuck is shown in the figures annexed. It consists of three parts—the chuck, the slide, and the ring. The chuck (*a a*) screws on to the lathe by means of the nozzle (*b*) projecting from behind. *c c* represents two pieces of steel, with dovetailed edges, secured to the chuck by four screws (*d d d d*). One of the steel bars projects a little over the chuck. The holes in this last plate, through which the screws *d d* pass, are of an oval form, to allow room for regulating the distance of the bars, in case of the slide getting any shake by wear or other circumstance. The corresponding bar on the opposite side of the chuck has no such allowance, as it does not require it; but, on the contrary, is secured by steady pins, so as to be always stationary.—The second part, or slide, of this elliptical engine (*ff*) works between the plates *c c*. On the front of this slide is fixed a screw, of the same thread and diameter as the end of the mandrel; and on the back of it are fixed two steel pallets (*g g*). They are secured to the slide by the screws and washers (*h h*); and there are two grooves (*i i*) cut in the chuck, for these to traverse in. Figs. 29, 30, and 31, represent the ring of the oval chuck. It has a hole in it, to allow it to pass over the screw of the mandrel; and as this ring is mostly required on one side, this aperture is made like a straight groove, having each end semicircular. This ring, to give it strength, and allow of an easy mode of fixing, is cast in one piece with the plate *k k*, which bears flat on the front or face of the lathe-frame. The ends are at right angles with the plate, and have two screw-holes in them, directly opposite each other. To these holes are fitted two steel thumb-screws (*l l*), the points of which bed in two holes on the side of the lathe-frame; and by turning both the screws *l l* in the same direction and at the same time, one advances, and the other retires; so that the one fills up the space the other leaves vacant; and the ring is always tight, and moves with regular motion. The top edge of the ring is filed flat, and is graduated into inches and parts. The divisions are read off by an index, which is engraved on the lathe-frame. When the index points to 0 in the division, the ring is concentric with the mandrel.

*Fig.* 26.

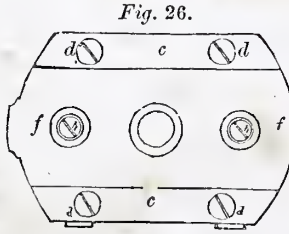


*Fig.* 27.

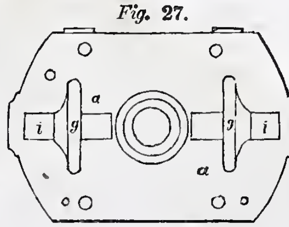


*Fig.* 28.

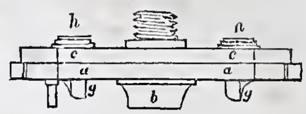


*Fig.* 29.

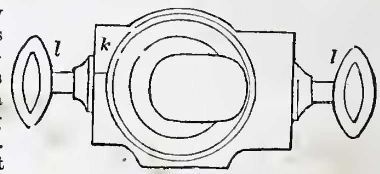


*Fig.* 30.

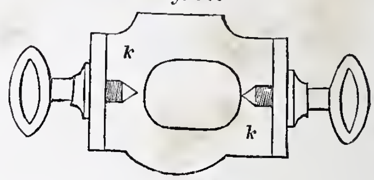
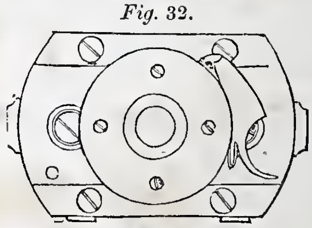


*Fig.* 31.

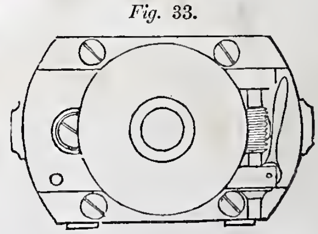
With respect to the action of this chuck—suppose, for instance, an oval to be wanted, whose transverse or greatest diameter is three inches, and the conjugate or lesser one two inches; find the difference between the two diameters, and take half the result for the eccentricity of the oval; that is, $\frac{(3 - 2) \text{ inches}}{2} =$ $\frac{1}{2}$ inch, the eccentricity. Now that this has been ascertained, take out the pin of the chuck; then move the ring on one side by the screws *l l*, till the Nonius points to half-inch on the scale, and which has placed the ring half-an-inch on one side of the mandrel. The size of the conjugate or lesser diameter depends on the distance of the tool from the centre of the work; and, of course, to describe the oval in question, the tool must be at the distance of one inch from the centre, half the sum of the conjugate.

*Fig.* 32.



*Oval Chuck, with Wheel and Click.*—This chuck, which is represented by fig. 32, differs from that last described only in the addition of a wheel and click.

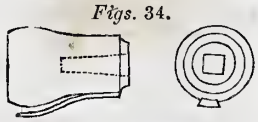
*Fig.* 33.



*Oval Chuck, with Tangent Screw.*—Fig. 33 represents an oval chuck, with wheel and tangent screw. For explanation of wheel and screw, and wheel and click, we must refer back to the description of similar parts in Eccentric Chuck.

*Pad Chuck.*—This chuck is shown in figs. 34. It is of a similar construction to the Drill Chuck, with square hole (fig. 17). It has also a square hole and a click and lever on one side, similar to the socket of a carpenter's brace. In this chuck may be fitted any kind of bits, to suit the work; each of these must have a notch filed on one side, to admit the click, which prevents their coming out.

*Figs.* 34.



*Pillar fluting chuck.*—This chuck is represented by figs. 35 and 36. It is composed of a socket *a*, which screws on the mandrel. *b* is a flat plate of brass secured to the chuck by the screw *c*, but which allows it a circular motion on the screw *c*, which motion is regulated by two steel screws *d d*, working in two projecting pieces *f f*, fixed to the nozzle *a*. *g* represents a parallel groove in the plate *b*, with bevelled edges. This is for the reception of the head *p*, which is secured to it by the screw and washer *l*.

*Fig.* 35.

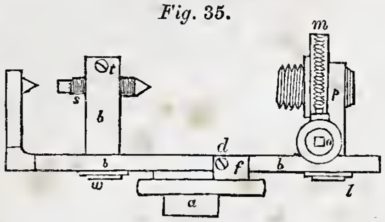
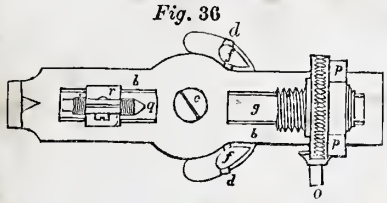



*Fig.* 36




On the front of the head *p* is a wheel *m*, with teeth on the edge, which is moved by the tangent screw *o*.

The double index on *p* is for reading off the divisions on the head of the tangent screw, and also on the circumference of the wheel *m*.

On the front of the wheel *m* is a screw corresponding in size and thread to the noze of the mandrel; the opposite end of the plate *b* is at right angles with the same, and has a steel point centre the same height from the plate as the screw on the head *p*. *q* is a similar groove to *g*, and is for the reception of a popit-head *r* used for shorter pieces. This head *r* is fitted into the groove *q*, and is fixed therein by the screw and washer *w*, by which it can be made stationary at any part of the same. The upper part of the brass head is provided with a steel centre screw *s*; it has also a slit lengthways about two-thirds of the whole height, and a tightening screw *t* on the side, by means of which, with the assistance of the slit, the screw *s* can be rendered immovable.

*Plain chucks.*—The general form is shown by fig. 37. The inside, which is intended to receive the work, is made rather conical, and largest in front, at a very small angle. To fix work in this chuck, the face of it which goes into the chuck should be turned true, and the same end of the work should be made of a corresponding cone to that of the chuck, in which case a very little driving will make it hold very firmly; for, if the chuck and work be similar cones, they fit together at every part of their surfaces. Work which has not been previously prepared as above described, may be fixed in this chuck, but not so well, for it can but hold a few of the most prominent points, and of course cannot be so firm. In large diameters it is sufficient to turn down a shoulder about $\frac{3}{16}$ of an inch long without reducing the work any more, as that is sufficient. It is very convenient for small work to plug up the brass chuck with wood—which wood can be turned to suit the work as occasion requires—for this combines strength, it being surrounded by the brass and the natural elasticity of the wood.

*Fig.* 37.

There is another advantage attending this method, namely,—If the chuck requires to be taken off from the lathe, when returned to it, it will run the same as before; but wood, being more easily compressed, sometimes screws on further than at others, and, consequently, gets out of truth.

*Prong chuck.*—This chuck has a steel prong (*a*) screwed into it, which has a sharp edge at right angles with the axis of the lathe; in the middle of this prong is a small projecting point.

*Fig.* 38.


Soft wood can be driven on with a hammer; for, being soft, it will not split. The other end of the wood must be supported by the popit-head, and, it is evident, as the prong enters the wood itself, it must carry it round with it. Hardwood may also be turned by this chuck; but then the groove for the knife edge of the prong must be cut with a saw, and the hole for the point must be drilled up, for driving, as in the last method, makes it liable to split.

*Running centre chuck.*—This chuck is represented by figs. 39, in which *a* is a steel-point centre, which is screwed into the centre of the chuck, and *b* represents a hollow steel centre which screws into the same hole when the centre *a* is removed—which is easily effected by the key—the sides of these centres being filed square, and of the same size as the key. *d* represents a straight groove to be described. This chuck is provided with a set of carriers which are indispensably necessary for performing any species of work with it. Fig. 40 represents one of its carriers.

*Fig.* 39.

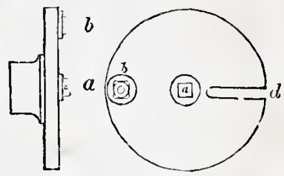



*Fig.* 40.

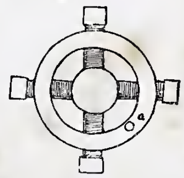
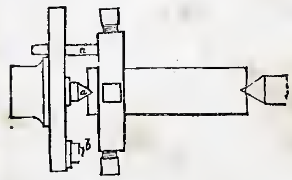



*Fig.* 41.



This is a ring of iron or steel, having four steel screws equally situated from each other. *a* represents a steel pin projecting out of the ring. Supposing, for instance, it is wanted to turn a stout piece of metal, as *m* in fig. 41, the ends must have centre holes made in them, and the work must be fixed in the middle of the carrier by means of the four screws, so that the pin *a* projects beyond the end of the work; next screw the work between the centre of the chuck and the centre screw of the popit-head, in such a manner that the pin *a* of the carrier is in some part of the groove *d* (fig. 39); and as the chuck turns, the carrier must turn with it, and as the carrier revolves, the work must also go with it. The centres *a* and *b* of the chuck may be used as the work requires it, and also the front centre of the lathe can be reversed if necessary.

It is very immaterial whether the work be fixed on the centre of the carrier, since the work revolves on its own centre.

*(To be continued.)*

# HISTORY.

## CHAPTER XII.

### ANCIENT EGYPT AND THE EGYPTIANS.

Our earliest notices of the Egyptian state represent it as monarchical. The earliest of all is in the book of Genesis. When Abraham first visited Egypt, about 1900 years before the Christian era, he found a Pharaoh ruling there. When Moses led the children of Israel out of Egypt, nearly 1500 years before the birth of Christ, he left a Pharoah reigning there. We have no grounds to decide whether these Pharaohs reigned over the whole of the tribes that drank of the waters of the Nile; but it is sufficiently evident that their sway must have been pretty extensive, and that their people had made considerable progress in the arts. Joseph sent up waggons for his father. The sending up of these vehicles seems to imply that they were not then to be found in the land of Canaan. The sudden transition of Jacob from incredulity to the conviction that his son Joseph must be alive in Egypt, upon seeing the waggons, strongly expresses the rarity of their appearance out of that land. Joseph was set in a chariot, which shows that men had learned in those early days to use vehicles in Egypt for purposes of pomp and luxury, as well as of convenience. The battle array in which Pharaoh set out to pursue the children of Israel, shows that chariots

had come in his day to be applied to purposes of war as well as of peace. The number and array of his forces, too, bespeak advanced skill in war, and extended dominion. The method adopted by the mother of Moses to hide her son, seems to indicate that the art of navigating the river had not advanced beyond what we find at this day on the Euphrates—the floating rafts of reeds or bulrushes daubed with pitch. At the same time, the pitch with which the frail bark of the future legislator of the Hebrews was *payed*, (if we may use a technical phrase,) implies one or other or both of two important facts: either that the narrow valleys west of the Nile were part of Pharaoh's realm, or that the Egyptians of that day had commercial relations sufficiently extensive to enable them to procure the asphaltum from the Dead Sea. Nor is it only for the purpose to which we are alluding, that this commodity was then employed. Already had the Egyptians learned their peculiar mode of preparing the bodies of the dead—a purpose for which much would be required. We read in the time of Moses of priests and magicians; and we are told that the legislator was instructed in "all the learning of the Egyptians." Finally, there were others of the children of Israel who had acquired skill in Egypt, of which their shepherd fathers, when they went down into that land, knew nothing. Bezaleel and Aholiab were skilful artisans, and could "grave on stones,"—one of the earliest arts that seems to have developed itself in Egypt. From these indications there can be no doubt that so early as the twentieth century before the birth of Christ, there were kings in that district of Egypt bordering upon Syria; and that so early as the sixteenth century before Christ, the sway of the Pharaohs of Mizraim extended over a wide domain, and their people had made considerable advance in the arts of agriculture, building, construction of vehicles, arms, and at least in priestcraft, if in no sounder knowledge.

The next appearance the Egyptians make in the Hebrew annals, is where it is mentioned that Solomon married a daughter of Pharaoh of Egypt. This alliance seems to have been contracted early in his reign, and he reigned forty years. Towards the close of Solomon's reign, we find Jeroboam, who afterwards reigned over the ten tribes, taking refuge from the persecution of Solomon with Shishak king of Egypt. We also read of a Shishak king of Egypt spoiling Jerusalem four years after the death of Solomon. It is, therefore, highly probable that the father-in-law of that monarch was the predecessor of Shishak. The name most nearly approaching to Shishak in the catalogue of Manetho, and in the hieroglyphics which have been deciphered, is Sesosis or Sesonchis; and this king is stated by Manetho to have been the first of the 22d dynasty that reigned over Egypt. It was not unnatural that the first of a new dynasty should be jealous of a powerful neighbour, son-in-law of the monarch he had dethroned; that he should give shelter to a fugitive of whom this neighbour was jealous, on account of a prophecy that he should succeed to the greater part of his kingdom; or that he should make war upon that neighbour's comparatively powerless successor.

It is not easy to determine the precise era of the Sesostris of Herodotus and Strabo. Coincidences in history show him however to have been the same called Sescasis by Diodorus, and Setharis by Manetho. This prince is placed by the Egyptian priest as chief of the 19th dynasty. It must therefore have been considerably prior to the attack of Shishak upon Jerusalem, that a king of Egypt was powerful enough to ravage with a numerous army—for it does not appear that he made any lasting conquest, as far at least as the confines of Cilicia to the north—and to carry home an immense booty and numerous captives. Pursuing backward the catalogue of Manetho, we find names which have been deciphered among the hieroglyphics; Minamon the beloved of Ammon, of the 18th dynasty; and Thauthmesis, the founder of that dynasty. By the dates of Egyptian chronology, the reign of Thauthmesis must have commenced in the year before Christ 1874, he must therefore have been contemporary with Abraham and Isaac. There is a circumstance attendant upon these dynasties to which I shall hereafter have to advert: they are designated the Bubastic, the Diaspolita, &c., names derived from cities or districts in Egypt. I shall give in the sequel my reasons for thinking that these dynasties may have succeeded each other, according as the petty chiefs of any of the districts waxed sufficiently strong to throw off his subjection to the chief of some other districts, who had previously lorded it over the others, and established himself in his stead. If I am correct in this conjecture, the Pharaoh visited by Abraham or his successor, being the first of a dynasty which took its designation from Diospolis or Thebes, must have reigned over upper as well as lower Egypt; thus placing the frontiers of the kingdom of the Nile-drinkers, even at that early period, exactly where they were under Psammytichus, whose reign commenced 662 years before the birth of Christ. The haughty monarch whom Joseph served, must have ruled a land equally extensive; and it will be remembered that the sacred annals advert to a very important change in the constitution of Egypt, occasioned by the famine revealed beforehand to Pharaoh in the dream interpreted by Joseph. These points of time being settled, bring the age of the great conqueror Sesostris to a period not very remote from Moses; and it increases our sense of the wonders achieved by that servant of God, when we reflect that he and his nomadic tribe were enabled to baffle the might of a monarch so powerful as the Pharaoh of Egypt must have been.

Returning to Shishak, and tracing the Manethan catalogue of Egyptian sovereigns towards our own time, we come to the Ethiopian conquerors of Egypt already mentioned, who reigned from 732 to 688 before Christ. These, be it remembered, cannot be viewed as kings of the Ethiopians—of all the Ethiopians. They are merely kings ruling over certain Ethiopian tribes combined into one state on the upper Nile, as the Ethiopians of the Egyptian union were on the lower. From the fragmentary notices we have of Sesostris, we are led to believe that he at one time turned his arms against the tribes living to the south of his dominions, and that, favoured by their not being organized into one state, he triumphed over them separately with ease. The lesson he taught these tribes was not lost upon them; and some centuries after his time, we find a sufficient number of them ranked under the banner of one king to retaliate upon Egypt, and subdue it in turn under their yoke. Egypt soon reasserted its independence; for in 662, B. C., we find a native prince again reigning from Syene to the sea. What remains, however, of the history of independent Egypt, was an incessant struggle for ascendancy between the Egyptians, and their kindred, the Ethiopians of the Upper Nile. It was probably the exhaustion, the result of this protracted strife, that made Egypt fall so easily before the arms of Cambyses in the year before Christ 525, when the sun of Egypt's independence set for ever.

Let us pause and look back. Our authorities are a catalogue of Egyptian monarchs which an Egyptian priest professed to extract from the hieroglyphic records of his country. The late progress we have made in hieroglyphic literature, has at least enabled us to recognise many of these names, thus far corroborating the assertion of Manetho. Light is occasionally thrown upon this dry catalogue from the narratives of contemporary Hebrews, and of Greeks of a later age who busied themselves about antiquarian lore. It is not much that we can expect from such scanty sources; but this at least seems established with tolerable certainty,—that from the beginning of the 20th century before Christ, down to the year 525 before Christ, Egypt, that is the valley of the Nile below the lower cataract, was organized into one state; that that state was monarchical; that it was, with few brief intervals, independent of foreign domination; that its monarchs more than once led their subjects upon predatory excursions on a great scale and with success, although they left no permanent settlement behind them. We must not, however, allow ourselves to form any very exaggerated notion of these foreign wars. They seem to have been confined to Syria proper, the shores of the Red Sea, and the Upper Nile.

Among the monuments of Egypt we enumerated in our last chapter as belonging indisputably to the era of independent Egypt, we mentioned the labyrinth. This monument stood or stands in the Arsinoitic nome, in the gap of the Lybian hills, above the site of ancient Memphis, through which a road leads to the lesser oasis, lying midway between the oasis of Anam and the great or Theban oasis. Of this structure, Strabo says:—"So many halls are said to have been massed together in this structure, because all the *nomei* (or districts) were wont to congregate there, and to celebrate a certain feast, both men and women assisting, on which occasion sacrifices were offered, and judicial sentences pronounced in cases of the weightiest moment; and each *nomos* congregated in its own especial hall." The same author informs us that the *nomei*, or districts, under the Roman government were the same which had obtained under "the kings." This is an epithet of dubious import: it is some-

times the designation used to imply the Ptolemies; but the connexion of the halls in the labyrinth erected before the Persian conquest with the *nomei*—their numbers the same—seems to carry back that division of Egypt to the independent era. The manner in which the *nomei* arose, and the manner in which they were designated, favours this view. We are told the *nomos* was the district round a certain city, and subject to its jurisdiction. They were not districts meted out by the directions of one who had obtained mastery over the whole land. They were independent settlements, extending till their boundaries met. Some of them are avowedly of Greek origin, some apparently of Persian. But these are of a later day—colonies upon unoccupied land; or a portion of an older *nomos* set apart for the new comers. The original *nomei*—we know not their designative name in the land's language—were those which had corresponding halls in the labyrinth. All the Egyptians, all the Nile-drinkers, were Ethiopians. They were self-governed, at least to a certain extent, each district within itself. There was a peculiarity of their land calculated to teach them the art and advantages of co-operation on a large scale, at an earlier period than other nations—the periodical inundation of the Nile. To render its fertilizing tendencies fully available—to prevent the damage this fostering leviathan in his unwieldy kindness might effect—works were required which could only be constructed by the joint labours of myriads. Some of the most obviously ancient structures of the Nile are the colossal causeways running from the river brink to the mountains. But of their erection, as of the digging of the first irrigating canal, even tradition is silent. The constructing of such works, however, required in men, and familiarized men to, organized exertion. Thus arose the central cities with their surrounding territories. But the inundation was one great phenomenon: it was important alike to all the Nile-drinkers that its amount should be known. Hence the forgotten origin of the Nilometers at Syene and Memphis. And once united for such a purpose—which year after year brought them together again just at the moment when the swelling of the river left them for a time in search of pleasure to fill up the hours of indolence—the idea of a central place of resort, where the labyrinth was afterwards reared, was most natural. Thither they repaired to compare notes about the prospects of the coming harvest. There they spent the hours in feasting, till the time of labour again returned. There the thoughtful endeavoured to lead their minds to a sense of gratitude to the Great Invisible, and sought to impress opinions which might render men more amenable to civil authority, or perhaps to prepare their minds for submission to a dominant *caste*. There the knotty points of law, which had puzzled the collective wisdom of a district, were submitted to the sages of assembled Egypt—the wisest among tribes which drank of the waters of the Nile. Thus were the Ethiopians of Egypt—the dwellers in the *Mizraim*—taught to feel that they were one.

How they came first to acknowledge a common head it were vain to conjecture; whether by conquest or election, or how far the authority of this head extended. I have already remarked that the names assigned by Manetho to his dynasties generally, indicate each to be indigenous in a specific town or district. It might be that the head—the *Phrè* of Egypt—was in fact elsewhere, and that the town from which he was selected was occasionally varied. It might be that the authority of the Pharaoh beyond his own district being very limited, it was easy for the ambitious ruler of another, as that other grew in power, to subvert his ascendancy. But, in either way, the independence and equipotence of the *nomei*, as indicated by the labyrinth and its purposes, are confirmed.

One most important step in the progress of the monarchy is incidentally recorded in the Book of Genesis. On the occasion of the seven years' famine, Joseph availed himself of the huge stores of grain in the royal granaries to purchase up the fee of the land from all except the priests. "And Joseph bought all the land of Egypt for Pharaoh; for the Egyptians sold every man his field because the famine prevailed over them: so the land became Pharaoh's. And as for the people, he removed them from one end of the borders of Egypt even to the other end thereof. Only the land of the priests bought he not; for the priests had a portion assigned them of Pharaoh, and did eat their portion which Pharaoh gave them; wherefore, they sold not their lands. Then Joseph said unto the people, I have bought you this day and your land for Pharaoh: and here is seed for you, and ye shall sow the land. And it shall come to pass, in the increase, that ye shall give the fifth part unto Pharaoh: and here is seed for you, and ye shall sow the land. And they said, Thou hast saved our lives; let us find grace in the sight of my lord, and we will be Pharaoh's servants. And Joseph made it a law over the land of Egypt unto this day, that Pharaoh should have the fifth part; except the land of the priests only, which became not Pharaoh's."

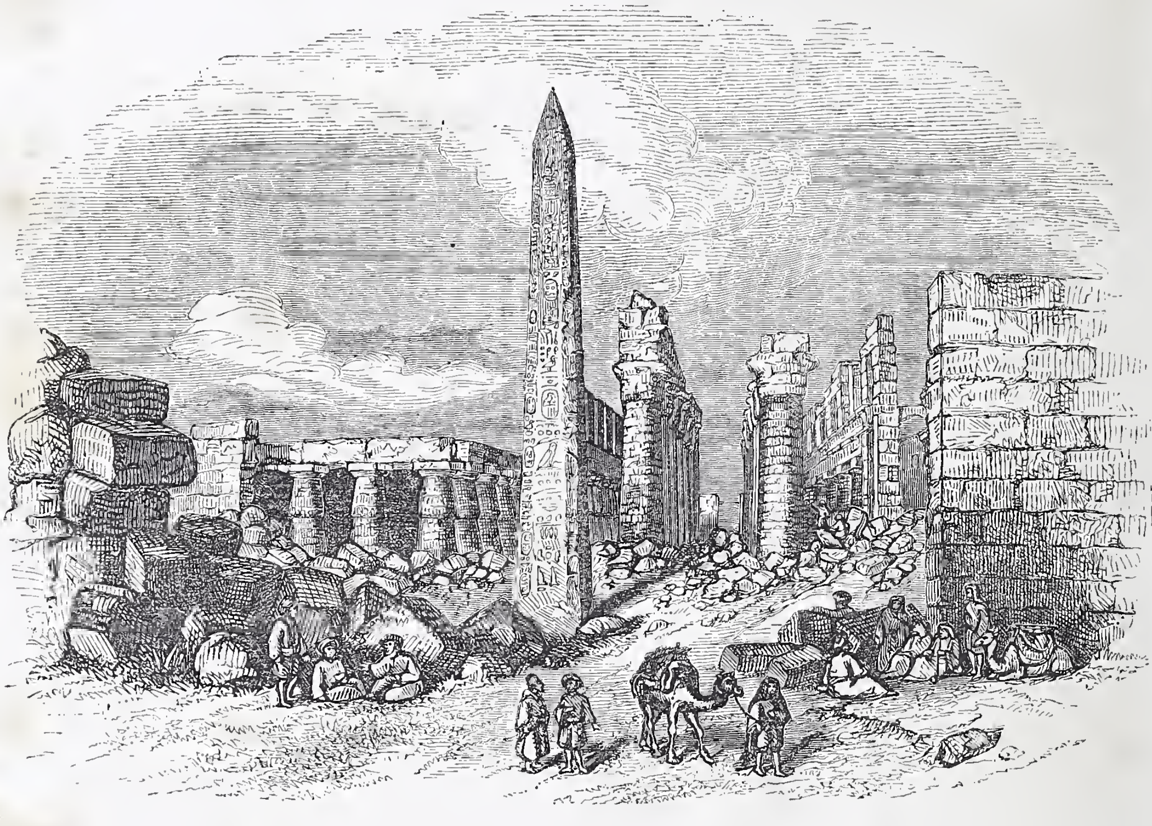
The effect of this was twofold. In the first place, the Pharaoh, now become a feudal monarch, was more powerful. In the second place, the priests, the only holders of allodial property, remained in worldly matters nearly on a footing of parity with the sovereign; while they possessed a yet stronger hold upon the superstitions of the people. In the kindred tribes of the Upper Nile, known to the Greeks and Hebrews by the vague gentile appellative Ethiopian or Cushite, the power of the priests was so great, that when they got tired of any king, and sent him word it was time to die, he had no resource but to comply with the best grace he could. Even in Egypt the extent of their power may be guessed from the legendary tale, that the last monarch of the Ethiopian dynasty in Egypt was inclined to abdicate, and retire into his own country, on being warned in a vision that his only chance of retaining the throne of Egypt was by killing all the priests.

Herodotus divides the Egyptians into priests, warriors, and husbandmen or artificers. This is the division of the Persian Egypt, but the origin of mere *castes*, it is evident from some facts which have survived dates prior to the overthrow of Egyptian independence. Twice in the annals of independent Egypt have we mention made of the warriors as a separate *caste;* once in the reign of Psammytichus, when they revolted for being kept too long unrelieved upon garrison duty, and marched in a body into Ethiopia; once in the reign of his predecessor, when the soldier *castes*, irritated at being mulcted under some pretence or other of a portion of their lands, refused to march against the invader—telling their monarch, priest-ridden, if not a priest himself, to see how his holy men would defend the frontiers. They did it tolerably well—by working a miracle. The bow-strings of the enemy, while encamping near Pelusium, were gnawed in pieces by field-mice, and the invading force, threatened with an attack in this defenceless condition, forced to retire.

The accumulated power in the hands of the monarch explains his greater facilities for the aggression of his neighbours; and the booty and slaves he carried home would further increase his strength, and enable him to play the freaks of power, the monuments of which still survive. With the exception of the Nilometer, the causeways, and canals of irrigation, all the works of ancient Egypt are either temples, or palaces, or sepulchral monuments, to feed the pride of kings. Whatever of art and science was known to the Egyptians was made tributary to the purposes of the king or priest. The husbandman tilled the king's land for a portion of the harvest, or the priest's for what he could get. The sculptor and the painter worked under the direction of the priest, chiefly upon funeral and monumental, or sacrificial objects. The all but servile condition of all who were not of royal blood, or priests, or of the warrior *caste*, facilitated the development of a multiplying of servile *castes*, the son being mechanically bound up to the business of the father. Hence expertness in some mechanical arts, and a timid submissive character akin to that of the Hindoo on the part of all but the privileged classes. In their patient and unambitious toil, the hordes of slaves, the produce of external wars, co-operated, and thus the land was cultivated like a garden, and studded with those monuments which still excite our amazement.

But man withered amid such institutions. Some knowledge the priests did possess: whatever was in Egypt was theirs—but it was nothing like what has been absurdly attributed to them Herodotus says that the priests of his day knew little save what related to the performance of the sacred rites. Strabo, after stating that they laid claim in his day to great knowledge, hesitates not to call them a parcel of quacks. Their astronomical knowledge was very limited. Ptolemy, whose writings contain all the most important observations transmitted to his time by the ancients, quotes Babylonian, Greek, and Roman, but not one Egyptian observation. Their year was not measured by the circuit of any of the heavenly bodies; it corresponded neither with the revolutions of the sun nor the moon, nor with the heliacal risings of the stars. The zodiacs at Esneh and Duibnah, about

which so much noise has been made, were found in temples erected at the very earliest by the Ptolemies; in so far as they can be deciphered they correspond with the indications of a marble celestial globe constructed at Rome during the time of the Antonines; and they bear strong indication of being mere ornaments put together by men who knew little or nothing of astronomy. The Egyptians seem scarcely to have progressed in celestial knowledge beyond the observation, that the heliacal rising of the dog-star was contemporary with the rising of the waters of the Nile. The priests knew the art of preserving appearances in order to awe the vulgar mind; and to them belongs the invention of that architecture which has been handed down from age to age of European civilization. The obelisks are theirs; though what was indicated by the form, or whether anything was indicated, is, and is likely to remain a mystery. The columns of the temples of Luxor and Karnak are ruins, in the first conception of what was idealized by the Greeks. The pyramids, with their substantial masonry, are theirs. These they had the genius to invent; they created architecture, and, in addition to the mere faculty of constructiveness, indicated a sense of the grandeur of collossal symmetry. This is all that can be attributed either to their architecture or sculpture. Their mythology was rude, deficient of a moral element; but we must not attribute to them the perplexity or immorality subsequently introduced. Herodotus tells us that only two deities—Isis and Osiris he calls them—were worshipped by all the Egyptians. Strabo tells us that the sacred bull might be met in every city, but that there were only three deified bulls,—Memphis, Heliopater, and Thebes. The multiplicity of gods dates from the conquest of Egypt; when the conquerors, forming an alliance with the priests, and endeavouring, by raising them to an equality by infusing jealousy and disunion among them, encouraged the development of local superstition, instead of one great national system of state religion. The influence of the Persians, and afterwards of the Greeks, multiplied the deities of Egypt, as it refined, but enfeebled their architecture, and rendered its hieroglyphics more complicated and enigmatical. This subject I shall have to resume, when, in treating of the effects of the revelation, I come to take notice of the Gnostic heresy



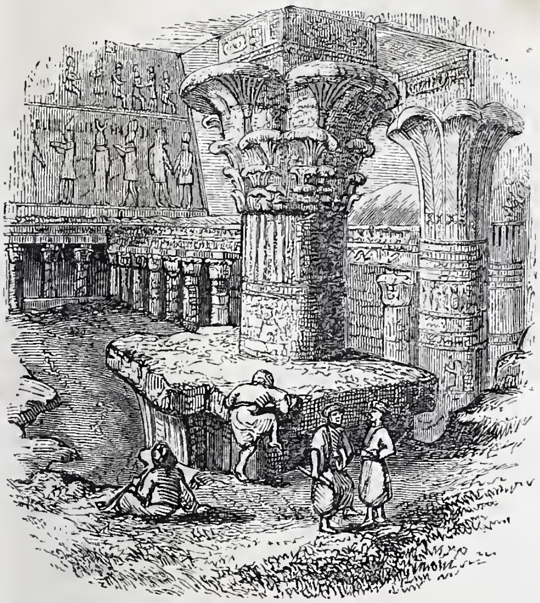
Karnak

In Egypt, the many were kept in a state of permanent childishness. The only characteristics fully developed in the rulers, were the wild thirst of adventure, and a love of pomp and parade. Among the priestly or learned class there were a smattering of land-measuring, some rude notions of sculpture and architecture, the first faint rudiments of law, the rudiments of the art of writing. We possess papyri traced with climatic characters of a date so early as the reign of Psammytichus. This is about the time of Manasseh in Israel, and long prior to the MSS. of any other nation that have come down to us.

The Egyptians have not lived in vain. They originated architecture—they originated the art of writing—they are said to have originated the art of land-measuring. If left without models and without inspiration to frame a government and a religion for themselves, they went astray—to err is human. They erred, but they likewise expiated their errors by their sufferings.

It will be remembered that my purpose in thus endeavouring to trace the domestic institutions of the Egyptians, was to enable us to guess at their condition under the Persian monarchy. That government was contented with rendering the royal tribute and the warlike force of Egypt available for its purposes. It did not interfere with any of the other arrangements of state. It left the laws and religion of the Egyptians as it found them. Some monarchs even sought to conciliate the priests by enhancing their wealth and the splendour of their rights. But the great

community continued to dwindle as before the conquest. The traditions regarding the early history of Egypt, which Herodotus picked up among them, show a nation fast sinking into the very twaddle of second babyhood.



COLUMNS AT EDFU.

## ASTRONOMY.

### CHAPTER IV.

ON THE LAWS OF TERRESTRIAL GRAVITY AND MOTION, AND ON THE DISCOVERY AND PROOF OF THE GREAT LAW OF UNIVERSAL GRAVITATION.

The science of Astronomy is divided into three branches:—*Descriptive*, *physical*, and *practical*.

*Descriptive* astronomy informs us of the distances, magnitudes, and densities of the heavenly bodies, and affords us an explanation of the various appearances to which their different motions give rise—such as, eclipses, the various phases of the moon, and the alternations of the seasons.

*Physical* astronomy explains the mechanism of the heavens, and the laws which regulate the motions of the heavenly bodies.

*Practical* astronomy gives an explanation of the nature and use of astronomical instruments, and details the method of making astronomical calculations, such as foretelling eclipses, the periods of the different quarters of the moon, &c.

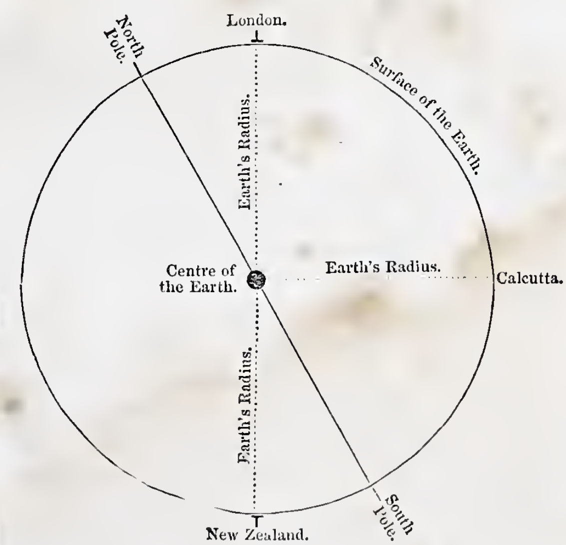
It may require close application of mind, but it appears the most natural plan, to begin by giving a general view of the second of these divisions—*physical astronomy*—by far the most sublime and interesting part of the whole science, and the foundation of the great superstructure of modern astronomy. Without a correct view of the theory of planetary motions, it is impossihle to acquire any information regarding the heavenly bodies which can have the most distant claim to be called astronomical knowledge; but a clear notion of the principles of physical astronomy will open up the beautiful harmony of the universe, the infinity, magnitude, and magnificence of the works of creation, and the transcendant power and skill of the great Architect; it will expand and elevate the soul, and will give rise in the contemplative mind to those sublime and tranquillizing trains of thought, and cannot fail to excite feelings akin to those of the Psalmist when he exclaimed, "What is man, that thou art mindful of him; or the son of man, that thou shouldest stoop to visit him!"

To enable us to understand the theory of planetary motion, it is necessary to glance at a few of the first principles of motion, as exhibited on the earth's surface; for, although we are indebted to Sir Isaac Newton for the complete and demonstrative proofs of the law of universal gravitation, still, unless the way had been paved for him, nay, even pointed out, by his predecessors in the science, and the laws of terrestrial gravitation and motion, as well in straight as in curved lines, discovered and explained, it is very questionable, powerful and original although his intellectual abilities were, whether his name as an astronomer would have ever been known to the world.

We must take a cursory view, therefore, of those laws of gravitation and motion which were discovered by Kepler, by Galileo, by Des Cartes, by Borelli, by Huygens, and by Hooke, and which enabled Newton to demonstrate—what several of these had previously asserted, but failed to prove—that these laws extended to the heavenly bodies, and that gravitation was the power by which all their various motions were regulated, and capable of being explained. We are compelled to undertake this introductory investigation, not so much for the purpose of ascribing to these individual philosophers that share of merit to which their discoveries entitle them, as to enable us fully to comprehend the laws of planetary motions, which it would be impossible to understand without this preliminary information.

From our earliest years we are accustomed to see almost all kinds of bodies, when lifted up or set in motion, possessing a tendency to fall to the lowest level; and, in common language, the power which thus impels them downwards is called their "weight." If one body exert a stronger power than another to fall to the earth, it is said to be "heavier;" the common notion being, that this power exists in the falling body. It is also remarked by the casual observer, that bodies fall to the earth perpendicularly, or in straight lines; and it may therefore be supposed, at first sight, that, by dropping a stone from the top of a tower in London, and another from the top of a tower in Calcutta, the lines which

Fig. 8.




they would describe in falling would be parallel. We must remember, however, that the earth is of a globular form, and that the distance between London and Calcutta is one-

fourth the circumference of this globe. If a stone, therefore, fall perpendicularly to its surface at each of these places, the one will fall at right angles to the other; and a stone on the east coast of the north island of New Zealand, would fall in a diametrically opposite direction to a stone falling in London, the one place being on the opposite side of the globe from the other. (See fig. 8.)

Hence it is obvious, that all bodies on the surface of the earth fall in straight lines to its centre; that the direction which is called "up" on one side of the globe, must be "down" on the opposite side; and that, as the earth makes a complete revolution round its axis every twenty-four hours, it follows, that the direction which we call "upwards" is not one instant the same in relation to objects external to our earth; in short, that the words "up" and "down" are merely relative terms, adopted by common consent to express our ideas, but they merely signify distance from, or nearness to, the earth's centre, there being, in reality, no "up" nor "down" in the universe.

We must endeavour, then, when we begin to turn our attention to the study of astronomy, to lay aside our preconceived notions of "up" and "down;" for if we do not possess a clear idea in our minds of the planets in boundless space revolving round their own axis, revolving also with their attendant moons around the sun—that central orb of our system—and surrounded on *all* sides, at inconceivable distances, by countless millions of other central orbs, with their attendant planets, we cannot acquire distinct notions of the simplest truths of astronomical science.

It has been long since proved, that a stone does not fall to the ground by any property solely inherent in itself, but by the attraction of the earth—denominated the *attraction of gravitation*—acting in the same manner as a magnet in attracting a small piece of iron—a phenomenon which is called *magnetic attraction;* and as magnetic attraction exerts a stronger power the nearer the iron is to the magnet, so it was soon discovered that the attraction of gravitation was greater the nearer the surface of the earth.

We have already seen that Kepler understood that all masses of matter possessed an inherent property of attracting each other. In his 'Epitome Astronomico Copernicanæ,' he says, that if two bodies were placed out of the reach of all external forces, and at perfect liberty to move, they would approach each other with velocities inversely proportional to their quantities of matter. For example, suppose two bodies, the one double the weight of the other, to be placed at the distance of twelve miles apart, in some portion of space beyond the attracting influence of any other body, they would attract each other, and come together like two magnets, but with different velocities; the smaller body would pass over eight miles, while the larger would only pass over four miles—whereas, if they had been of equal size, each would have passed over six miles. Kepler also says, that the moon and the earth mutually attract each other, and are prevented from meeting by their revolution round their common centre of attraction; and that the tides of the ocean are the effects of the moon's attraction drawing up the waters immediately under her. He also explains how this attraction between two bodies, will produce a deflection of one of them into a curvilinear path.

Galileo made many important discoveries in the laws of gravitation and of motion, as displayed on the surface of the earth. He established by demonstration the fact, which was at that time strenuously opposed by the disciples of Aristotle, that, were it not for the resistance of the atmosphere, all bodies, whether light or heavy, large or small, would fall to the ground with equal velocities—descending from equal heights in equal times. This fact is well illustrated by what is called the "guinea and feather experiment." A guinea and feather are placed upon a small shelf in the upper part of the tall receiver of an air-pump: the air being completely exhausted, the shelf is upset by touching a wire outside, and the two bodies drop to the bottom at the same instant.

Galileo, also, not only discovered that bodies fall to the earth with a uniformly accelerated motion, but he calculated the *rate* of this acceleration. As it was impossible to measure this rate by watching bodies falling perpendicularly, he had recourse to an inclined plane, accurately divided into parts. On this plane was a smooth rounded groove, in which a polished ball could roll down with a small amount of friction, and at such a velocity as would enable him to mark the times it required to pass over the different parts. After several hundred experiments, and after measuring exactly, by an ingenious expedient, the time the ball took to roll down the whole length of the plane at various inclinations, as well as over the different portions into which it was divided, he discovered that, instead of the ball rolling down the first half of the length of the plane in half the time it took to roll down the whole length, it rolled down only *one-fourth* of the length; and that it made no difference whether the plane was much inclined or little inclined, the same thing occurred at *any* inclination. He found, if his plane were sixteen feet long, and placed at such an inclination as that a ball would take four seconds to roll to the bottom, that during the first second it only rolled over *one* yard, during the next second it rolled over *three* yards, during the third second it rolled over *five* yards, and during the fourth second it rolled over *seven* yards; or, in other words, at the end of the first second, the ball had passed over *one* yard; at the end of the next second, or in half the time, it had passed over *four* yards; at the end of the third second, it had passed over *nine* yards; and at the end of the fourth second, it had passed over the whole length, or *sixteen* yards.

Galileo invariably found, to whatever inclination he raised his plane—which proves that the same rule must apply when the plane is vertical, or when the ball falls freely to the ground—that the spaces passed over in each succeeding second respectively, were in the ratio of the odd numbers, 1, 3, 5, 7, 9, 11, &c. For instance, if the ball required six seconds to roll to the bottom, it passed over seven times the distance during the fourth, nine times during the fifth, and eleven times the distance during the sixth and last second, which it did during the first; and at the end of any of these seconds, the space passed over from the commencement of the fall was always in proportion to the square of the time elapsed. For instance, at the end of the third second, it had passed over, from the commencement, nine times the space; at the end of the fourth, sixteen times the space; at the end of the fifth, twenty-five times the space; and at the end of the sixth, thirty-six times the space, which it had passed over at the end of the *first second.*

From these experiments, Galileo thus discovered the important law, that the earth's attraction diminishes as the distance from the earth increases; not, however, in a simple ratio, but *inversely as the square of the distance.* For example, the surface of the earth is a certain distance from the centre, and bodies are there attracted with a certain force; at twice this distance from the centre, the amount of this force is not diminished by one-half, but by four times the amount; at three times the distance, the strength of the attraction is only one-ninth; at four times the distance, one-sixteenth, and so on, decreasing continually in proportion as the square of the distance increases. Thus, a body weighing 18 lbs. at the earth's surface,—4,000 miles from its *centre,*—would only weigh $4\frac{1}{2}$ lbs., or one-fourth, at the distance of 4,000 miles from the earth's *surface;* 2 lbs., or one-ninth, at the distance of 8,000 miles; $1\frac{1}{8}$ lb., or one-sixteenth, at the distance of 12,000 miles. In the same manner we infer, that if a body fall 16 feet and 1 inch per second at the earth's surface—which it has been proved by experiment to do—at the distance of 4,000 miles *from* the earth, it will only fall 4 feet $\frac{1}{4}$ inch, or one-fourth the distance it falls at the surface of the earth; at the distance of 8,000 miles, one-ninth part of the distance it falls at the earth, and at the distance of 12,000 miles, one-sixteenth part of the distance, or 1 foot and $\frac{1}{16}$th part of an inch per second of time.

We have thus seen, that the velocity of every falling body is uniformly accelerated as it approaches the earth, from whatever height it falls; that the rate of this acceleration is in a regular mathematical ratio, caused by the constant

operation of the force of the earth's attraction, which perpetually gives new impulses to the falling body, and increases its velocity; and that, if the distance at which a body commences to fall to the earth be known, the rate of its velocity during the first second, or during any period of its fall, can easily be calculated. The fact that falling bodies are uniformly accelerated in their velocity, is rendered obvious to the senses by watching, from an opposite height, the rolling of a large stone down a steep declivity on the side of a hill: at first the velocity is slow—it gradually becomes quicker and quicker, till, by the time the stone reaches the bottom, the force and velocity become so great as to overcome every obstacle that may come in the way, and it buries itself in the ground.

The law thus explained, which regulates the motion of bodies falling to the earth, applies equally to bodies propelled upwards, acting, of course, in a reverse order. As a body is uniformly accelerated by the earth's attraction in falling to the ground, so, by the same agency, a body propelled upwards is uniformly retarded; so that, if any body were projected perpendicularly upwards with such force as that it would take five seconds to reach its highest altitude, it would rise nine parts of the whole distance in the first second, seven parts in the next, five parts in the third, three parts in the fourth, and only one part in the fifth and last second; at the end of this period it would remain nearly stationary for an instant, and then return to the ground, passing through the same spaces in the same time, in a reverse order.

There appears to be some analogy between the manner in which the force of attraction varies with the distance, and that in which the intensity of *light* and *heat* varies. The intensity of light and heat is found to diminish in proportion to the square of the distance; and in the case of light, the reason of this law is more easily understood, for if a piece of wood an inch square be held at the distance of one foot from a candle, it will hide the light, at the distance of two feet, from another piece of wood of two inches square, containing four times the amount of surface of the first; and at the distance of three feet, it will hide the light from a board three inches square, or from nine times the amount of surface; at the distance of two feet, therefore, the light is spread over four times the surface, and must have only one-fourth the intensity; at the distance of three feet, it has only one-ninth the intensity, and so on.

The intimate nature or cause of the force of attraction between bodies, will perhaps for ever remain a mystery; philosophers call it gravitation, but they merely know it from its effects, and as that power by which bodies are retained on the surface of the earth, although it is whirled round with a velocity of 68,000 miles per hour, and that power, also, which regulates the motions of planets, satellites, and comets, and retains them in their orbits.

In addition to this power of attraction, which was found to be an inherent property of all matter, Galileo pointed out another property which he showed to be inherent in every particle of inanimate matter, and which has been called its *inertia*, or indifference to rest or motion. He established the fundamental truths, that if a body could be placed at absolute rest, it would remain so for ever, if left unacted upon by any external force; and that every body, on receiving an impulse or disposition to move, would move onwards for ever in a straight line in the direction of the impelling force, provided it continued undisturbed by any other force. The tendency of bodies continuing to move when once put in motion, is, to some extent, illustrated by a common top, which continues spinning for some time after the motive force is withdrawn; but its motion is ultimately arrested by friction, the resistance of the air, and gravity: diminish several of these opposing forces, by placing it on a smooth surface, and in the exhausted receiver of an air-pump, and it will continue in motion ten times as long. A pendulum, also, if suspended by a delicate thread and set in motion, will continue moving for a considerable time; but suspend it in an exhausted receiver, and it will continue moving for a whole day, after having been once set in motion. Again, if we roll a polished ball on a common field, the influence of friction, the resistance of the atmosphere, and gravity, will soon bring it to rest; diminish the amount of friction, by rolling it on smooth ice on a level plain, and it will roll to a much greater distance; and if it were possible completely to remove the influence of friction, and to propel it with such force as would overcome all opposing forces, it would move round the earth at a *uniform velocity;* and if it moved round the earth once with a *uniform velocity,* it would start on its second round with the same force which carried it round before, and would, in this manner, continue revolving round the earth for ever, if arrested by no new counteracting force. In the latter case, however, the original impulse would require to be powerful beyond conception, to overcome the resistance of the atmosphere, and the opposing power of the earth's attraction, so near its surface. But suppose the ball removed 4,000 miles, which is twice as far from the earth's *centre* as the earth's *surface* is, the force of gravity would then be only one-fourth the intensity, and the resistance of the atmosphere would be almost nothing, so that, at this distance from the earth, the ball would only require an impulse of one-fourth the power to make it revolve round the earth for ever, like the moon; at ten times the earth's radius, or 40,000 miles distant, it would only require one-hundredth part of the original impulse, and so on—by Galileo's law of gravitation, diminishing in power as the square of the distance increases. Hence it is obvious, that the greater the distance from the centre of attraction, the less original impulse will be required, and the less will be the velocity; and as the attractive power of the sun binds all the planets in their orbits, as we shall afterwards see, we have here also the reason why their velocities diminish in a certain proportion as their distance from the sun increases, in accordance with Kepler's third law.

But, by the *inertia* of matter, bodies have a tendency, not only to continue moving when once set in motion, but also to move in *straight lines* in the direction of the impulsive force. Even in circular motion this tendency is illustrated. The water from a grindstone in rapid motion passes off in straight lines; a stone whirled round in a sling, the instant it is set at liberty, darts off in a straight line; in galloping on horseback round a narrow circle, the rider has great difficulty in preventing himself from being thrown outwards; by whirling a ball of soft matter, such as moist clay, very rapidly round an axis, it will bulge out all round the middle, and become compressed or flattened at each end around the axis, assuming what is called an *oblate* shape. From the enormous rapidity with which the earth revolves round its axis, it ought, in theory, to have assumed this shape, and be flattened round the north and south poles; and this is exactly the form which it is proved in several ways to have, but which, from the opposing causes, can only occur to a certain extent.

The force which produces this tendency in matter revolving with a circular motion to pass off in straight lines, is called, in philosophical language, the "*centrifugal force,*" and is directly in proportion to the velocity of the moving body—the one increasing and diminishing with the other; the force of gravitation, acting in opposition to this centrifugal force, is also called the *centripetal force;* when both these forces, acting upon any body, are equal—the one exactly counterbalancing the other—the body is said to be in *equilibrium,* and as long as this equilibrium exists, the body will continue to revolve with uniform velocity.

The laws of gravitation and motion, as above explained and illustrated, may be thus briefly expressed:—

1*st. All bodies within the sphere of the earth's attraction, and uninfluenced by any other force, fall in straight lines to its centre.*

2*d. All bodies, large or small, light or heavy, would fall from the same height with equal velocities, and in equal times, were it not for the resistance of the atmosphere.*

3*d. The force of attraction between two bodies is directly in proportion to their weights, or to the quantities of matter in each.*

4*th. All bodies fall to the earth with uniformly accelerated velocities.*

*5th. The force of the attraction of gravitation, exerted by any body, diminishes in proportion as the square of the distance from that body increases.*

*6th. Every body in nature would continue in a state of rest, or, if once set in motion, it would proceed for ever in a straight line with uniform velocity, if uninfluenced by the attractive force of any other body.*

*7th. Motion is in proportion to the force impressed, and in the direction of that force.*

With reference to the last-mentioned law, it may be easily understood that motion will be quick or slow, in proportion to the strength of the propelling force, and it may also be quite apparent that the motion of a body will be in the direction of the force applied; but it is not so obvious what will be the direction of a body, if propelled by two or more forces of different intensities, and in different directions. If, for instance, a round ball be struck by several forces in different directions, it will not roll off in a *zig-zag* manner, corresponding to the effect of these different forces, but it will proceed in a *straight line* in such a direction as will express the united effect of them all. Suppose a round ball, placed at the corner of a platform 10 feet broad by 20 feet long, and suppose it to receive two blows, one of a certain strength, which would send it across the platform in the same time as another double the strength would send it to the end, the ball would neither move in the direction of the one force nor the other, but would fly in a straight line along the diagonal, and reach the opposite corner of the platform in the same time in which either of the blows, singly, would have sent it across or to the end. Any two instantaneous forces, therefore, acting upon a body in different directions, will propel it along the diagonal of a parallelogram, whose sides are in exact proportion to the intensity of each of the forces respectively.

Curvilinear motion is different from the above: the direction of a body in this case is neither in a straight forward, nor in a diagonal, but in a *curved* line. Curvilinear motion is the result of the action of two forces of different natures upon a body, one of them an *instantaneous impulse*, which, as we have already seen, always tends to produce uniform motion in a straight line; the other *continuous*, which acts unceasingly in bending or deflecting the body from this straight line, causing it to pass through a line more or less curved. All bodies projected forward on the surface of the earth, sooner or later fall to the ground, and are examples of curvilinear motion. Water flowing from an aperture in the side of a full cask, a cannon ball projected from the mouth of a cannon, both fall in curved lines; the pressure of the superincumbent fluid, and the explosive power of the powder, being the propelling forces in these cases respectively; and in both cases, the attractive force of the earth, acting continuously across the course of the stream and the path of the ball, bends or deflects them downwards, and makes them form curves. The shape of the curve which a body describes, depends on the intensity of the original impulse. If a body be projected with but a slight force, the curve which it will describe will be very much bent, and it will fall to the ground at a short distance off; if, however, the original impulse be very intense, the course of the body will at first be almost horizontal, or in a straight line; but, by the continuous action of gravity, it will be gradually deflected from the horizontal line, and the course will be bent more and more downwards, till it finally reach the ground.

It is a remarkable law, however, of projectiles, that, *whether the original impulse be great or small, so as to send it to a greater or less distance off, the projectile will reach the ground from the same height in the same time.* It may appear strange, at first sight, that any body propelled forward will fall to the ground from the *same height* exactly in the *same time*, whether that body be projected to the distance of ten, twenty, a hundred, a thousand, or even ten hundred thousand yards. We must remember, however, that the force of the earth's attraction acts as strongly, whether a body be flying in a horizontal direction, or falling perpendicularly downwards: if a body move rapidly, the space passed over will be great; if slowly, it will be small; but it makes no difference to the attraction of gravitation whether the velocity forward be quick or slow, or whether there be any forward motion at all, the body being acted upon by the same force will fall to the ground at the *same time* from the *same height*. In the above supposed case of a body being projected forward with such velocity as to make it revolve round the earth, the primary impulse gives the ball a tendency to proceed forward for ever in a straight line; the force of the earth's attraction constantly tends, with a uniform amount of power (at the same height), to bend it from this straight line. If the original impulse, then, be sufficient to overcome the force of this attraction, and to retain the body in *equilibrium*, during one revolution round the earth, the body, by its own *inertia*, cannot stop its motion in the slightest degree, consequently it will revolve for ever, unless some other force interfere with its motion.

These laws of gravitation and of motion were well understood, as far as they applied to bodies on the earth's surface, before Sir Isaac Newton was born. Nay, even Copernicus surmised that the same principles might be found to be diffused among the heavenly bodies, guiding and preserving their motions. After him Fermat, a celebrated mathematician of the fifteenth century, seems, to a certain extent, to have had accurate notions of these great laws, as influencing the motions of the celestial orbs; and, as we have already seen, the immortal Kepler went a step farther, and distinctly announced the great principle of *universal gravitation*. Dr. Hooke, also, a contemporary of Newton, had very clear views on this subject; and at a meeting of the Royal Society, in 1666, the very year in which Newton began to direct his attention to gravitation, he said, "I will explain a system of the world very different from any yet received, and it is founded on the three following propositions:—1st. That all the heavenly bodies have not only a gravitation of their parts towards their own proper centre, but that they continually attract each other within their spheres of action. 2d. That all bodies having a simple motion will continue to move in a straight line, unless continually deflected from it by some extraneous force, causing them to describe a circle, an ellipse, or some other curve. 3d. That this attraction is so much the greater as the bodies are nearer."

The general nature of the planetary motions were thus discovered, or rather conjectured, and described. That splendid repository of astronomical observations—the Greenwich Observatory—was founded in 1675; and that patient, persevering, and accurate investigator and observer, Flamstead—a second Tycho, with means infinitely superior at his command—was elected the first astronomer-royal by Charles II. Flamstead spent upwards of thirty years of unwearied and unremitting labour in forming a catalogue of three thousand stars, and in collecting a vast store of important lunar and planetary observations; and, as Kepler was indebted to the observations of Tycho upon the planet Mars, for the discovery of his celebrated laws, so was Sir Isaac Newton indebted to the accurate observations of Flamstead upon the moon, for the discovery, or rather the demonstrative proof, of universal gravitation.

Tycho and Flamstead chose almost identical paths in the field of astronomical investigation; still, it is rather remarkable that there should have been such a similitude of circumstances connected with their names and their histories. Both were unjustly treated by their native countries; during their lives, and for long after their deaths, their investigations were neither rewarded nor appreciated as their merits deserved. The labours of the former were the indispensable foundation of the fame of Kepler; those of the latter, that of the fame of Newton; and both Kepler and Newton, instead of showing proper gratitude and acknowledgment for the obligations they were under to these great men, exhibited a jealousy, a want of temper, and a degree of injustice towards them, which dim the lustre of the sage in the narrow-minded jealousy of the man.

Sir Isaac Newton was born at Woolsthorpe, a humble manor-house in Lincolnshire, in 1642, the year after the

death of Galileo. It is worthy of notice, that both he and Kepler were premature births, each being born at seven months, and were so puny and delicate children, that, in both their cases, their parents despaired of their reaching mature age. During his boyhood, Newton was employed about the small farm which was superintended by his mother after the death of his father, and he was chiefly remarkable for his mechanical ingenuity. Having exhibited an ardent love of learning, by neglecting all his other avocations whenever he got a book, he was sent to school by an uncle, and subsequently to Trinity College, Cambridge, which he entered in his eighteenth year, and where he soon greatly distinguished himself. In 1666, when about twenty-four years of age, it is related that, during the prevalence of the plague at Cambridge, he retired to the country, and, while sitting musing in his mother's garden one day, an apple happened to fall to the ground from a tree; this trivial circumstance directed the train of his thoughts to that mysterious property, by which all bodies are endowed, of attracting one another. Can the conjecture be true, thought he, that it is by the same mysterious power which draws this apple to the earth, that the heavenly bodies are retained in their orbits? Copernicus threw out the conjecture; Kepler affirmed its truth; Huygens and Borelli were of the same opinion; and, that very year, Dr. Hooke expounded the doctrine of universal gravitation before the Royal Society. Neither loose conjecture, however, nor strong assertion, could claim the title of demonstrative proof; and nothing less than absolute demonstration of the fact would satisfy the mathematical mind of Newton. To the proof of universal gravitation, therefore, he resolved to apply all the powers of his giant intellect.

Newton soon saw, that, if he could prove that the attractive force of the earth was actually of the same intensity at the moon, as it ought to be by Galileo's law of gravitation—diminishing in proportion to the square of the distance—that if the moon, uninfluenced by any other force, would move towards the earth at the same rate as she ought to do by this law, *then* he could tell whether the moon was retained in her orbit by the attractive force of the earth.

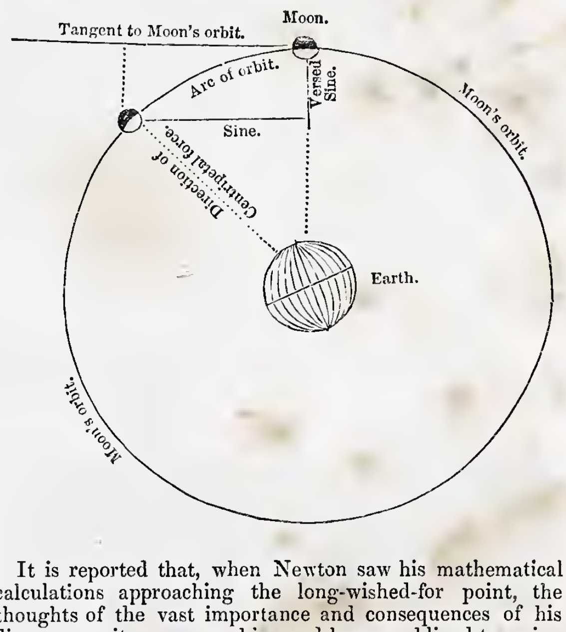
We have already explained that remarkable law of projectiles which was first discovered by Huygens, and which proves, that if any body is acted upon by two different kinds of forces—one instantaneous, propelling it forward in a straight line, the other continuous, such as gravity, unceasingly bending it from this straight line—that body moves in a curved line; and that the amount of bending or deflection from this straight line, in a given time, is as much a measure of the force of gravity, as if the body fall in a direction perpendicular to the centre of the continuous attraction. The moon, then, is evidently under the influence of two forces, otherwise she could not move in a curved line; and, if Newton could prove that the moon, in any part of her orbit, made, in a second of time, such a bend or deflection from a straight line touching that orbit, as would be exactly equal to the distance she ought to fall to the earth in one second, by Galileo's law—if she were solely acted upon by the influence of gravity—then would he have reached the summit of his desires and hopes, and then would he have proved that the moon is retained in her orbit by the same force by which an apple falls to the ground.

To enable Newton to solve this grand problem, certain data were necessary. He must know exactly the nature of the moon's orbit, the velocity at which she moves, and the exact space which she passes over in a given time; and he must also know the exact distance of the moon from the earth, so as to ascertain the force of the earth's attraction at that distance. For everything connected with the orbit of the moon, her velocity, and the exact space she passes over in a certain time, he was indebted to the indefatigable labours of the accurate Flamstead; but the distance of the moon was at that time very incorrectly stated, and Newton's calculations were, of course, inaccurate. He laid them aside, therefore, for several years, till Picard of France, by making a much more correct measurement of a degree of latitude, gave a near approximation to the diameter of the earth, and hence arrived at the distance between the earth and the moon. Picard discovered that the moon was sixty times farther from the surface of the earth, than the earth's surface was from its centre. Newton, therefore, resumed his calculations with renewed vigour, and, going upon the assumption that the force of gravity decreased in proportion to the square of the distance, hence inferred that that force ought to be ($60 \times 60$) 3600 times less at the moon than it would be at the earth's surface; consequently, as the force of gravity at the earth makes a body fall sixteen feet and one inch per *second*, it ought, at the moon, to make it fall only sixteen feet and one inch per *minute*, or 3600 times less.

Now, what is the distance, asked Newton, to which the moon is deflected from a tangent to her orbit in one minute? Is it sixteen feet one inch? If so, *then* the theoretical distance to which she ought to fall, and the actual distance which she does fall, are exactly equal: *then* is the problem solved; then is bare conjecture transformed into demonstrative proof, and the theory of *universal gravitation* established for ever.

By the aid of the accurate observations of Flamstead, Newton was enabled to prove that the length of the versed sine of an arc described by the moon, or the perpendicular distance to which her course would be deflected from the tangent or straight line touching the point where the calculation of the time commences, was exactly sixteen feet one inch per minute—the exact distance which she would fall to the earth, if entirely abandoned to the action of the earth's attraction. (See fig. 9.)

Fig. 9.




It is reported that, when Newton saw his mathematical calculations approaching the long-wished-for point, the thoughts of the vast importance and consequences of his discovery quite overcame him, and he was obliged to resign his concluding calculations to be completed by a friend. In obedience to this great law of universal gravitation, he saw the various satellites of our system bound to their primary planets, while, by the same force, satellites, planets, and comets were bound in their orbits around the sun. The sun himself, with all his retinue of planets, moons, and comets, has been since proved to be constantly shifting his position in space, probably revolving round some other orb infinitely more mighty and glorious than he. This other orb, with his enormous retinue of suns and systems, may be probably revolving round some other superior orb, and so on, till the whole universe—as far above the comprehension of man in magnitude and splendour, as its boundary exceeds

the boundary of the orbit of our earth—revolves in endless harmony around that Almighty Being, "with whom a thousand years are as one day, and one day as a thousand years!"

## LACON'S PATENT IMPROVEMENTS IN LOWERING SHIPS' BOATS.

In the numerous disasters at sea which have lately occurred, as, for instance, in the cases of the *Orion* and *Amazon*, the principal loss of life has been attributed, apparently with too much justice, to the difficulty almost always experienced in lowering the ship's boats. The apparatus at present in common use for that purpose appears to be very imperfect, and urgently to call for improvement. In the first place, the operation is slow, and, in the second place, the boat is seldom lowered so as to fall horizontally upon the water, and is thus frequently swamped. In the case of both the *Orion* and the *Amazon* this disaster occurred to several boats; and we find, in the account of the dreadful calamity with which the latter was overwhelmed, that "some of those who escaped first attempted to get possession of the best life-boat, placed nearer amidships, but lost so much time in their vain efforts to remove her from the cranes or crutches, that the approaching flames drove them off, and they then took to the after life-boat, in which they left the ship."

It is evident that these cranes must be abolished, and some other method introduced for effectually supporting, without straining, the boats. Accordingly, we find that the Report of the Naval Members of the Board of Trade on the loss of the *Amazon*, contains the following recommendation:—"The fatal consequences of this obstruction (the cranes) have been shown in the evidence, and we should hope the use of these cranes, or of any contrivance which obstructs the ready lowering of boats, may be forthwith discontinued. While upon the subject of the boats, we may advert to the lamentable loss of life which was occasioned by some of the boats being improperly lowered, and by the tackles not being readily unhooked. *The means of lowering boats evenly, and of readily disengaging the tackles, together with plugs that are self-acting, are desiderata wanting throughout the naval service.*"

These acknowledged desiderata seem to be very effectually supplied by Mr. Lacon's improvements, for which he has taken out a patent, and which have been fully described by that gentleman himself in an able pamphlet on the subject.* These improvements will be understood by reference to the annexed engravings.

Fig. 1.

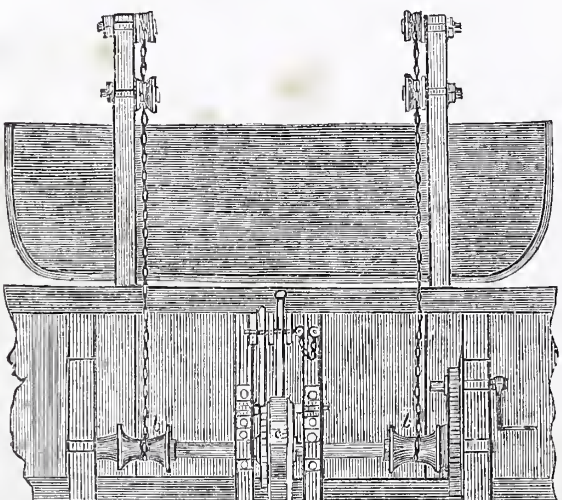


Fig. 2.

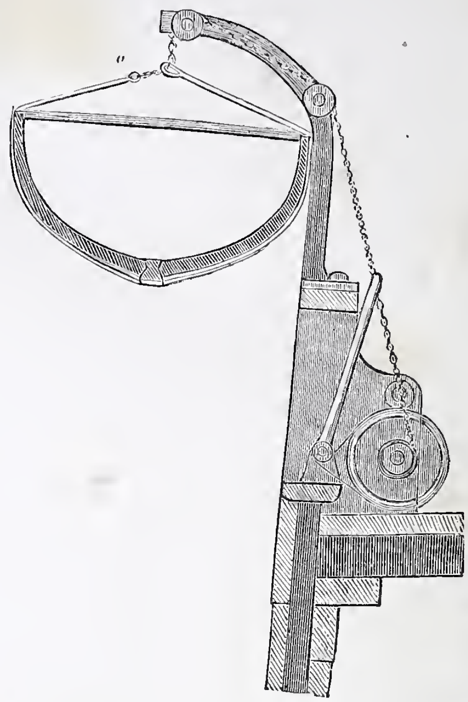
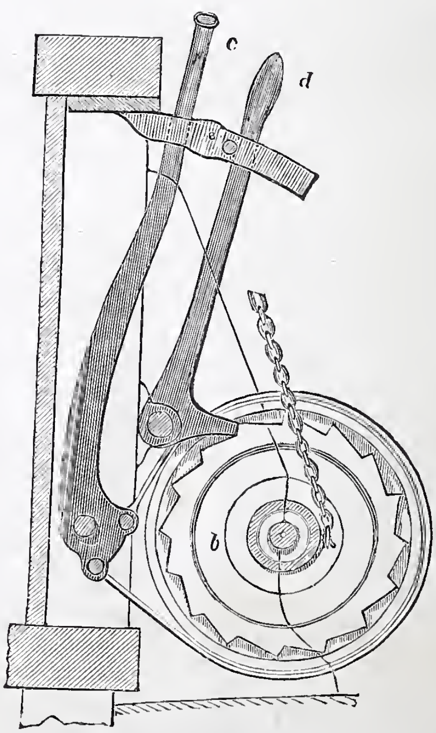


Fig. 1 is a side elevation of the bulwark and lowering machinery, viewed from the ship's deck; fig. 2 is a transverse section of the boats, davits, and gear; and fig. 3 is an enlarged view of the friction-brake and pall-barrel, denoted by the letter *c* in fig. 1.

Fig. 3.

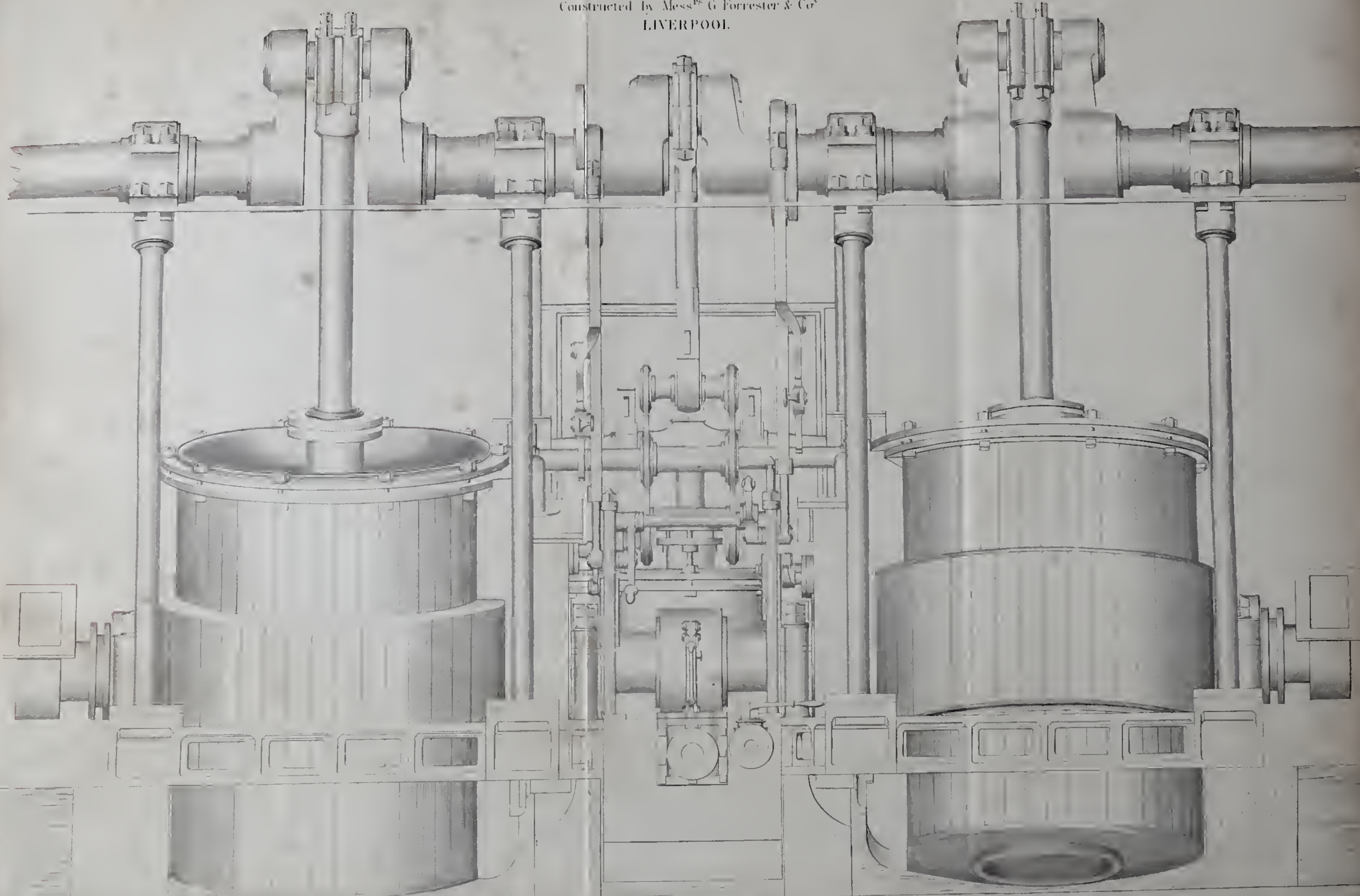


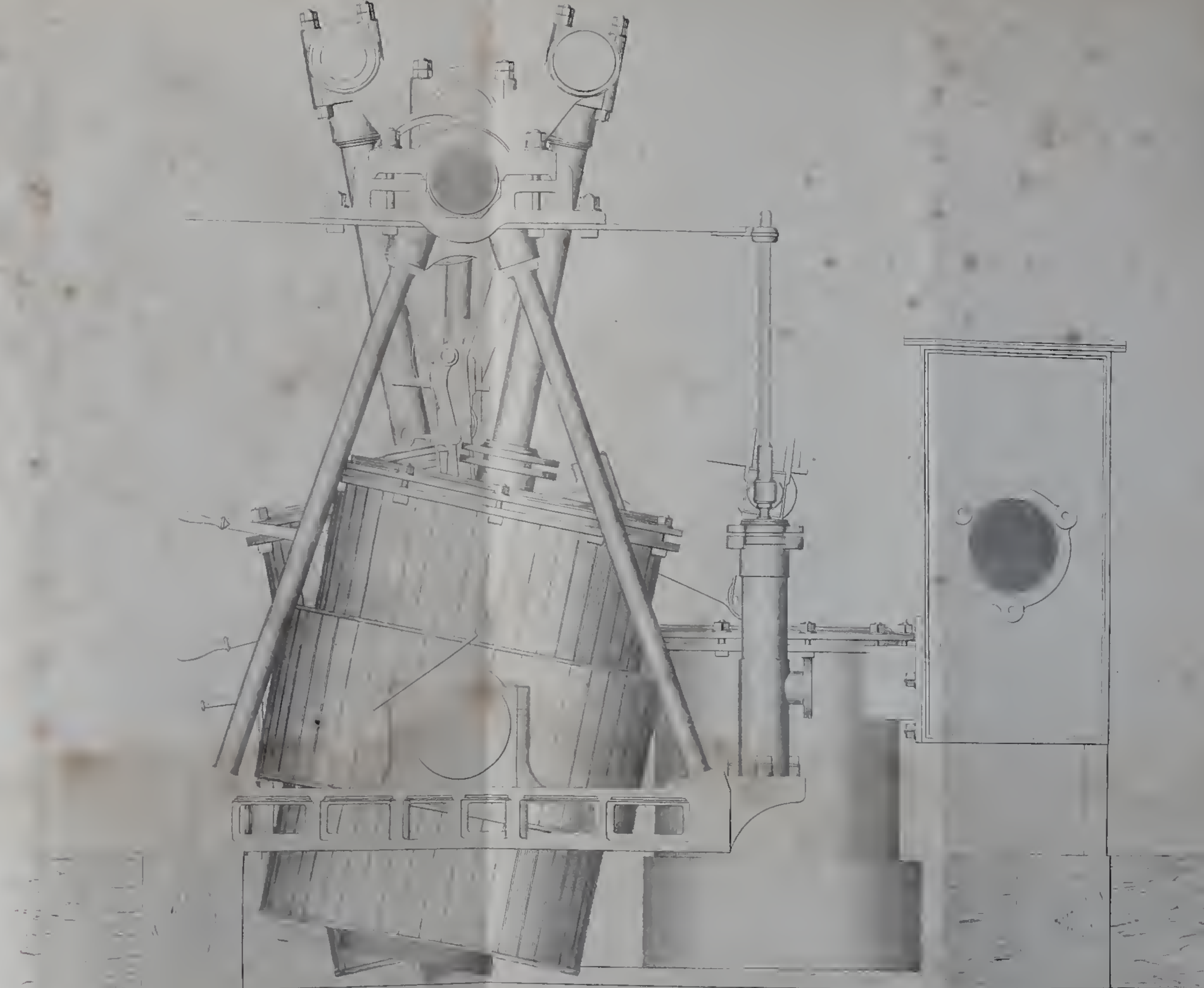

* On the Management of Ships' Boats, by W. S. Lacon, H.C.S. London: Parker, Furnwall, and Parker.

OSCILLATING MARINE ENGINES OF 45 H.P.

Constructed by Mess.rs G. Forrester & Co.

LIVERPOOL





It will be seen, from fig. 1, that the hoisting and lowering gear consists of a single-purchase crab, on the main spindle of which are the two chain-barrels, *b*, *b*, and the friction-brake and pall-barrel, *c*. The boat may be hoisted up, as usual, with tackles; and while thus suspended, two broad slings or belts, having a ring at each end, are to be passed round and underneath the bow and quarter of the boat. One end of each sling is made fast to the suspending chain or rope, while the other end is also secured to the suspending chain by a lashing, as shown at *a*, in fig. 2. The chains are carried over sheaves or pulleys to the concave barrels, *b*, *b* (fig. 1), in each of which there is a pin, by which the chains are made fast. The crab, to the main spindle of which these barrels are fixed, works in standards fixed to the deck and bulwarks. In the centre of the spindle is the brake and pall-wheel. *c* (fig. 3) is the brake-handle, and *d* the pall-handle. These are secured by a pin, *e*, which can only be removed by a key; and Mr. Lacon proposes that the officers only be intrusted with a key for this purpose, to prevent panic-struck passengers from seizing the boats by main force. He proposes also that a painter be attached, at all times, by one end to the bow of the boat by two half-hitches, and by the other end by two half-hitches, to the ship, and that the lashings by which the boat is secured to the ship's side when at sea, shall be passed round small timber heads on the bulwark (instead of lashing them, as at present, to eye-bolts in the ship), so as to be easily thrown off, cut, or let go.

When, in any emergency, the order is given to lower the boat, two men get into it, and throw off the lashings, retaining, however, some turns of the lashing of the slings, the ends of which they hold in their hands in readiness, while a third man takes his station at the lover of the friction-straps or brake-handle. The latter, when the men in the boat are ready, lifts the pall from the ratchet-wheel, by throwing back its handle or lever into a self-acting catch, and, withdrawing the bolt, presses forward the lever of the friction-strap or gripe, by which he can lower the boat slowly or quickly, whatever weight may be in her. She cannot fail to descend horizontally; and on reaching the water, if the men in the boat let slip the remaining part of the lashing of the slings, the boat will be clear, and will ride alongside the ship in safety by means of the painter.

By suspending the boat in the manner thus described, with two stretchers, to prevent the slings pressing in the gunwales, the straining of the boat is avoided, while the use of 'chocks,' 'keel-cranes,' and 'crutches,' is dispensed with; and the boat can not only be lowered quickly, but must go down into the water upon an even floor. We hope, therefore, to see Mr. Lacon's method generally adopted, and even its adoption rendered obligatory by law.

## FORRESTER'S OSCILLATING MARINE ENGINES.

*(Illustrated by two Plates.)*

We here present our readers with a good example of this excellent species of engine, the merits of which, for marine purposes, have latterly become so extensively recognized. The small space they take up, and the efficiency of the connection between the piston and the crank-shaft, which amounts, indeed, to the effect of an indefinitely long connecting-rod, combine to render them perhaps the most valuable of all designs for marine purposes. Accordingly, the steeple engine, which found favour so long, is now, in great measure, superseded by the oscillating class. The beautiful Clyde steamer "Victoria" has lately been furnished by Robert Napier, Esq., with splendid engines on this principle, embodying all the important points of excellence of which it is susceptible, with all the latest improvements. In these ("Victoria") engines, the piston is attached to the rod by means of a nut on the under side, and is fitted with metallic packing, with ten springs. The air-pump is set in front of the engines, at an angle of 62½ degrees, and is worked directly from the paddle-shaft by a central crank. The general plan of the oscillating engines is shown in the annexed drawings, which are themselves sufficiently explanatory of Messrs. Forrester's system of construction.

With regard to the "Victoria," we may state, that on the late trial trip of this vessel, the rate of motion of the piston was found to be 364 feet per minute. At this speed the engines, although nominally of 75 horse power, at 200 feet per minute, were actually yielding a power of 136 horses, by the Admiralty rule.

## COPELAND'S PATENT SELF-REGULATING BLOW-OFF FOR MARINE BOILERS.

The arrangement sketched in the annexed drawings is a self-regulating blow-off apparatus, recently patented in this country by Mr. C. W. Copeland, of the United States' Navy. It proceeds on the principle of making the supply of feed-water regulate the amount of the water blown off. The drawings

Fig. 1. Fig. 2.

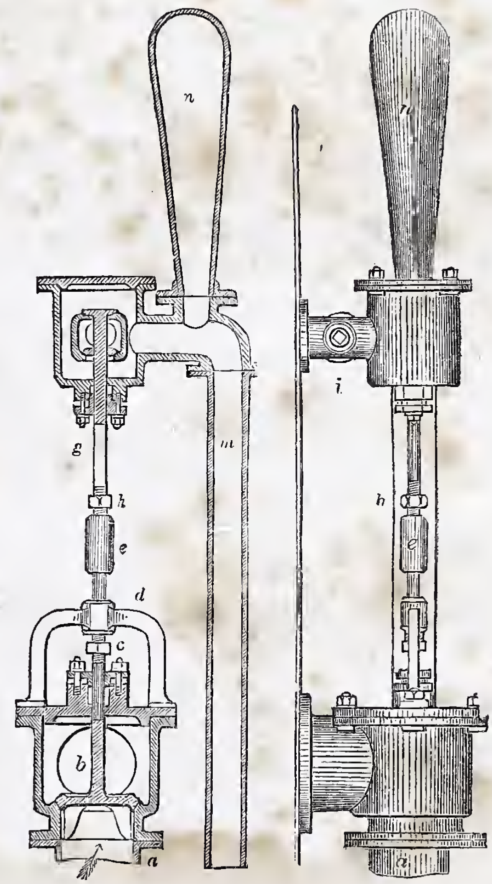



exhibit the apparatus as applied to the boilers of the *Mississippi* steamer; fig. 1 being a front elevation, and fig. 2 a side elevation in section.

The water delivered by the feed-pump enters through the pipe, *a*, and lifts the check-valve, *b*, some certain height, depending upon the quantity of water entering the boiler. This may be regulated by the nut, *c*, on the stem of the valve, which is prevented rising beyond a certain height by the guard, *d*. On the stem is a socket, *e*, in which the stem of the blow-off valve, *g*, works freely. On this stem is also a regulating nut, *h*, which the socket, *e*, lifts in rising, and the blow-off valve with it. At every stroke of the feed-pump, therefore, *if water be delivered into the boiler*, a certain fixed

quantity is allowed to escape by the blow-off valve. The stop-cock, *i*, is attached between the boiler and the blow-off valve, for convenience of shutting off the communication when it is desired to examine the valve, and a pipe is led from this to any part of the boiler from which the blow-off is to be taken. The blow-off pipe, *m*, is connected to the ordinary system of pipes leading to the sea, as is usually practised; the air-vessel, *n*, is attached for the purpose of preventing the shocks to the pipe, which the intermittent action of the blow-off is liable to produce. It is obvious that the general arrangement may be varied to suit circumstances.

The advantages of this system, as enumerated by the author, are these:—1st, The quantity of water blown off bears a definite fixed relation to the quantity evaporated, so that a steady density of water is maintained in the boiler; 2d, The valve is directly before the fireman's eye, and should it cease to operate can be readily detected; 3d, It is constantly in operation, instead of being periodical, like blowing off by hand; 4th, If no water is supplied to the boiler, none is blown off; and 5th, By its uniformity and regularity of action, the arrangement economizes fuel.

At present there are three different methods of blowing off the partially saturated water from marine boilers. The first is "blowing by hand," in which the fireman or engineer blows off, at certain intervals of time, the amount of water required; a second method is the "constant blow-off," in which a small blow-off cock is kept constantly open to the extent necessary; and a third is the method by "brine-pumps," which are constructed of fixed dimensions, and kept in constant operation by the engineer. Each of these methods is liable to serious objections. By that of "blowing by hand," the water is not kept at a uniform density, and fluctuates between certain extremes, while accidents frequently occur from carelessness of men in neglecting to shut the blow-off cock until the water is blown out, and the boiler burned, possibly causing an explosion; this method, moreover, requires constant attention, whereas the patent blow-off, once properly adjusted, is self-regulating. The "constant blow-off" may, in like manner, be left open by carelessness after the engine is stopped, and thereby the water be blown below the flues, or perhaps the whole be blown out; it makes no noise in its operations, and there is no mode of detecting a stoppage in the pipe, or any other obstruction or derangement, except by a critical examination. Finally, the "brine-pumps" are not only liable to the same objection as the "constant blow-off," in regard to the means of knowing of their operation, but they are much more easily deranged, and therefore still more objectionable on that score. The dimensions of the pumps, moreover, are fixed at the time of construction, so that they extract from the boiler a fixed quantity of water at each revolution of the engine, whatever be the rate of evaporation, the quantity of water taken off depending only on the velocity at which the engine is working, and this varies with draft of water, wind, sea, &c. It must consequently happen, that if the dimensions of the pumps are sufficient to take off the requisite quantity of water at the minimum speed, they must be much more than sufficient at the maximum speed, and hence an unnecessary waste of fuel in heating a supply of water renewed more frequently than is required. In these respects, Mr. Copeland's "blow-off" is decidedly superior to any of those mentioned: it is self-acting, independent of carelessness or inattention on the part of the men, and the amount blown off is exactly regulated by the supply. A more complicated arrangement is used on board the West India Mail steamers, but this of Mr. Copeland's seems, from its simplicity and efficiency, calculated to supersede all others.

# INDEX TO VOL. I.

C



D



E

L



M



N

# LIST OF PLATES.



END OF VOL. I.

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